Draft Final Report
Workshop Planning for Coastal Climatologies in the Southeastern United States

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EXECUTIVE SUMMARY

The Coastal Services Center (CSC), National Climatic Data Center, and National Oceanographic Data Center of the National Oceanic and Atmospheric Administration (NOAA) are developing a series of coastal climatologies. These climatologies would build upon traditional meteorological and terrestrial climatologies (e.g., winds, precipitation, temperature, soil moisture, river flows), add marine parameters (e.g., sea surface temperature, chlorophyll concentration, salinity, dissolved oxygen), and lead to products that will be used by state and local managers who are faced with climate-sensitive decisions.

A workshop for weather, climate, and marine-sensitive decision-making, planning, or assessments in the Atlantic coast of the southeastern United States was convened to facilitate the development of coastal climatologies. Coastal climatologies are unique because they would consist of a blending of marine and terrestrial-based information. Stakeholders attending the workshop represented public and private entities in eight areas: agriculture, coastal transportation, energy conservation and planning, environmental quality, fishery management, natural hazard mitigation, recreation and tourism, and water consumption. Information provided during the workshop consisted of weather, climate, and marine information that are currently being used by stakeholders as well as sources, availability, cost, and delivery systems for this information.

The purpose of this report is to provide recommendations on the development of applications and databases that will support coastal managers, specifically those faced with weather, climate, and marine-sensitive decisions. This report outlines specific illustrative applications from eight unique user areas along the Atlantic coast from Virginia to Florida. These user applications are based on structured queries as well as stakeholder response and feedback received at the workshop.

Based on stakeholder input, a coastal climatology product would contain information on atmospheric and near-shore oceanographic parameters that allows for a probabilistic characterization of constraints and enablers of economic and environmental activities and systems. Recommendations were provided for coastal climatology products in specific areas of coastal agricultural pest forecasting, hydroelectric power generation and reservoir management, open-water seafloor mound dredge material disposal, integration of climate-fisheries interaction research into fisheries management, hazard mitigation through beach renourishment, coastal water sports, predicting surf conditions for coastal water sports, hurricane evacuation planning and implementation, and reducing non-point source pollution.

Beyond these specific recommendations, several cross cutting coastal climatology issues were identified through workshop discussions. Collectively, these key issues need to be addressed in order to build successful coastal climatology products. The cross cutting issues can be grouped into five categories: 1) definition of coastal climatology, 2) observing systems, 3) forecasts, 4) product creation and delivery of coastal climatology products, and 5) follow-up to production of coastal climatology products. Each of these issues is discussed below.

1) *Definition of a coastal climatology* – An opening task of workshop participants was to define coastal climatology, specifically the distinction between a coastal climatology and traditional land or marine climatology. Our definition of coastal climatology recognized that the coastline constitutes a major contrast between land and the sea in terms of temperature, humidity, wind, and aerodynamic roughness. Atmospheric phenomena in the coastal region, especially those in the micro- to meso-scale dimensions, are produced by the presence of the coastline. These coastal phenomena extend about 150 km landward and seaward from the coastline (Rotunno 1994). Examples of coastal meteorological phenomena include the sea breeze, sea-breeze-related thunderstorms, coastal fronts, haze, fog, enhanced winter snowstorms, and strong winds associated with coastal orography.

Many stakeholders included environmental and economic systems pertinent to their interests in their definition of coastal (i.e., they were reluctant to put spatial bounds on information that may impact their decision making). Coastal climatology products should address system-oriented needs rather than location-specific information. In addition, an effective coastal climatology would include marine parameters so that end users can assess near-shore conditions in addition to terrestrial conditions. This need for two types of information is what truly separates coastal climatology users from land or marine climatology product users. A coastal climatology product without contiguous terrestrial and marine observations or forecasts may be of limited use to coastal climatology users.

2) *Observation Systems* -- Workshop participants recommended the deployment of more near-real time terrestrial and marine observing systems with more parameters, increased time resolution, and seamless access across observation platforms. Although specific client problems called for specific types of observing systems, an opinion was that existent resources were lacking in some fashion. Part of the problem in identifying needed data is that many coastal managers do not have sufficient background in meteorology and physical oceanography to describe the specific information needed for their decisions. However, the authors interpret "better" data as more wave, current and wind data nearshore (5km from the shoreline) within bays at a county and sub-county spatial resolution with real-time reporting, and a means for placing real-time data within a historical perspective.

A review of existing moored C-MAN buoys (the source most frequently cited for buoy data by workshop participants) and their location along the southeastern United States coast elucidates some of the difficulties outlined by participants in utilizing the existing observation network. A 5:1 ratio exists between coastal buoys and coastal counties, indicating a discontinuity between the scale of observation (buoy) and the scale of decision-making (county/sub-county). Thus, new coastal climatology products should address this disparity through either the addition of more data collecting buoys, the integration of non-Federal observing system similar to SEA-COOS objectives, or creation of accurate spatial interpolation methods from the existing buoy observation network to down scale observations for decision maker needs.

3) *Forecasts* -- Nearly all workshop participants found the use of weather, marine, and climate forecasts essential to their operations. They identified temporal gaps between short-term forecasts (e.g., 7-day weather) and climate forecasts (e.g., greater than one month). They recommended integrating weather, marine, and climate forecast results across consistent (and

statistically practical) spatial and temporal resolutions. These recommendations may be easily attained. The National Weather Service provides a suite of forecast products from hourly to seasonal. Specific location forecasts of temperature, dew point, relative humidity, wind speed and direction, sky conditions, *et cetera* are available at 3-hour increments for 3 days in advance and 6-hour increments for days 4 through 7. Probabilistic forecasts of temperature and precipitation are available over 6 to10-day and 8 to 14-day periods. Similar to monthly and seasonal forecasts, these “extended range outlooks” are for the whole country. Our sense is that stakeholders would like extended-range and climate outlooks for specific geographical locations. It is also our impression that the National Weather Service is pursuing downscaling projects at their local forecast offices.

4) *Product Creation and Delivery* -- Participants agreed that collective design of coastal climatology products by stakeholders and scientists could lead to the creation of valuable tools. Collaboration also fosters trust between parties that makes it more likely that a product would be integrated into decision processes. Several stakeholders recommended the development of personalized products that meet their specific information needs. The delivery of such products could be achieved on the Web through the development of a user interface that allows the end user to tailor available data, visualization of the data, and analytical tools to fit their needs. Such individual crafting might include selection of geographic area of interest, suite of parameters and observations, time frame and temporal resolution, and output preferences, such as geo-referenced tables and maps.

5) *Follow-up* -- Most participants were honest enough to admit their expertise did not include weather, climate, or marine science. NOAA should assume that most of the end users for coastal climatology products are specialist in their own operations and need expert guidance when it comes to integrating coastal climatology products into their activities. An interesting outcome of this workshop is the demonstration for the need for future research initiatives to clearly define components of various coastal climatology products. Such initiatives should provide blueprints for coastal climatology products in single or similar core areas. NOAA should be prepared to provide training in the form of workshops, tutorials, or on-site seminars in support of their products. Recommended partners for this type of outreach are SeaGrant Programs, NOAA Coastal Service Center, and Regional Climate Centers.

TABLE OF CONTENTS

INTRODUCTION

A recent socio-economic analysis of the coastal and oceanic economy of the United States determined that coastal states were responsible for 75% of the nation's gross state product in 2000 (Colgan 2003). Nearly half of the nation's economy came coastal watershed counties, specially near-shore areas accounting for only 4% of the land area, produced more than 11% of the economic output. Since the coastal regions possess such vast economic opportunities as well as cultural attractions and historical factors, population density has increased significantly along the coast. Coastal economic growth has surged in areas such as Alabama, Florida, Mississippi, and North Carolina where employment has increased by more than 50%. As a result, many coastal communities are faced with maintaining strong economic growth, improving infrastructure for industry as well as residential growth, and minimizing the deleterious impacts on coastal environment.

Infrastructure management and environmental protection by coastal communities and governments is complicated by their ability to respond and adapt to climatic variability and change. In 1997-1998, seasonal and inter-annual variations in climate, such as the El Niño Southern Oscillation, caused 25 billion dollars in economic impacts, including property losses of $2.5 billion and crop losses of $2.0 billion (NOAA 2003). In response to this challenge of integrating knowledge of climatic variability into commerce and environmental protection, NOAA has prioritized the understanding of climate variability and change for transferring knowledge into decision-making skills that enhance society's ability to plan and respond.

The purpose of this report is to facilitate the development of applications and databases that will support coastal managers, specifically those faced with weather, climate, and marine-sensitive decisions. NOAA is taking a phased, regional approach to this planning so that lessons learned in the first regions examined can be more easily applied to planning in subsequent regions. The geographic focus of this report is the southeastern United States, which has been defined as Atlantic coast from Virginia to Florida. This report outlines one specific, illustrative application from eight user areas (Table 1). To provide a systematic approach to developing the plan, universal questions were explicated in each application area.

- Identify the data and analytical tools needed to produce the product.
- Identify sources and likely costs for those data and analytical tools and assess their quality and suitability with respect to these core uses.
- Describe the present format of the data and analytical tools and any changes needed to the format of those data and tools in order to facilitate their use.
- Assess the accessibility of the data and analytical tools to the target users.
- Identify data and information gaps with respect to the core uses and make a preliminary assessment of the likelihood that current technology and government programs could fill those gaps.
- Identify cultural, educational, or institutional obstacles within the coastal management community that would impede that community from adopting the likely products from this coastal climatology effort.
- Describe the training that likely would be needed within the coastal management community for that community to make use of the products from this coastal climatology

effort. Identify and assess key training providers within the private sector and government capable of providing the training.

A stakeholder workshop was our means for collecting information on data, products, models, decision tools, and a host of other requirements for a series of coastal climatologies. Information provided during a workshop at the NOAA Coastal Services Center on October 21-22, 2003 aided in the construct of a set of core user sectors for coastal climatologies (see Appendix A for agenda and Appendix B for participant list, see Appendix C for areas of interests outside core areas provided in this report). The 45 workshop participants represented public and private entities involved in eight core areas: agriculture, coastal transportation, energy conservation and planning, environmental quality, fishery management, natural hazard mitigation, recreation and tourism, and water consumption. The design of the workshop included a series of short lectures on meteorological and marine observations systems. Upon receiving this initial information, the participants divided into working groups to discuss and outline specific recommendations as to the content, structure, and communication of coastal climatology products. The first task for working groups was to describe decision-making, planning, or assessments in their core areas and the integration of weather, climate, and marine parameters into those areas. This task identified weather, climate, and marine information that are currently being used by stakeholders as well as data sources, data availability, data cost, and delivery systems. The sources of data, forecasts, and products were primarily NOAA, but information sources also include other Federal agencies, universities, and private corporations. The second major task of the working groups was to answer a series of what-if questions that sometimes led to a deconstruction of existing decision making structures and heightened expectations of NOAA data and products (see Appendix D for questions posed to working groups).

The initial step in construction of a series of coastal climatologies is the definition of the terms coastal and climatology. For this workshop and report, the coast is defined as 100 km landward of the shoreline to 100 km seaward, which roughly equates to the geographic extent of the sea breeze system (Rotunno 1994). However, participant's definitions the coast varied depending on their core user area. Some alternative definitions included the Coastal Plain and adjacent shallow ocean waters, brown water ecosystems, and United States territorial waters. Many end users defined the coastal zone to include environmental and economic systems and activities pertinent to their core area rather than specific geographical features (i.e., they were reluctant to put spatial bounds on information that may impact their decision making). Thus, coastal climatology products would address system and activity oriented needs rather than simply providing information on a specific location or coastal zone. Further, a coastal climatology would need to include oceanographic variables so that end users could assess near-shore conditions in addition to terrestrial conditions. The need for both marine and terrestrial-based information distinguishes coastal climatology users from other climatology product users. A coastal climatology product without spatially transparent terrestrial-marine observations or forecasts may be of limited use to coastal climatology users.

The definition of climatology supplied by workshop participants is much more specific than the traditional long-term weather patterns "over periods of time measured in years or longer" (Hidore and Oliver 1993, p. 4). In particular, the end users view climate as a "constraint" or "enabler" of economic and environmental activities or systems. For example, summer produces conditions that enable tourism along the coast in the form of beach visitation. In contrast, hurricane season constrains tourism in that people are less likely to visit the beach due to the threat of tropical storms or hurricanes. Further, since climate is not static, climatic variability creates variability in the enabling or constraining of systems and activities. Continuing the tourism analogy, a particularly rainy summer in a tourism area may lead to decreased number of tourists and diminished economic return. Probabilistic assessment of whether a system or activity will be constrained or enabled by change in atmospheric and oceanographic parameters can help convey climatic variability and uncertainty. Using the tourism analogy again, an end user in tourism or recreation may like to know what the general probability of a tourist season being disrupted by a hurricane. In regard to the temporal aspect of climate, a concise definition of the time frame in which climate variability should be assessed for economic and environmental activities or systems was not provided by the workshop participants. Below the monthly timeframe, real-time meteorological observations are often employed in decision-making. It is difficult to completely separate climatological and meteorological data used in management decisions because they are used simultaneously to make decisions. This report will maintain distinctions along a time continuum between climate forecasts, weather forecasts, weather observations, and climate records.

Based upon the needs expressed by the workshop participants, a coastal climatology product may be defined as information, including both atmospheric and near-shore oceanographic parameters, that allows for a probabilistic characterization of constraints and enablers of economic and environmental activities and systems. However, the specific nature of information to be included in coastal climatology products was more difficult to ascertain from workshop participants. The coastal management community believes that climatology information is extremely important for decision processes but specific types of information that are important are defined rather ambiguously. Clear ideas as to the type of real-time meteorological data required for decisions exists, but once an attempt is made to couch such information within the climatological framework, the clarity is lost. In this report, we will provide our expert opinions on specific weather, climate, or marine information products requested by users. Accordingly, one of the most important outcomes of this workshop is the demonstration for the need for future research initiatives to clearly define components of various coastal climatology products. Such initiatives should provide blueprints for coastal climatology products in single or similar core areas.

This report will provide recommendations for the development of coastal climatology products for the eight core areas (agriculture, coastal transportation, energy conservation and planning, environmental quality, fishery management, natural hazard mitigation, recreation and tourism, and water consumption). A cross cutting summary of coastal climatology issues that are salient to all of the eight core areas will illustrate the manifold interrelated processes that require weather, climate and marine information

CORE USER AREAS FOR COASTAL CLIMATOLOGIES IN THE SOUTHEASTERN UNITED STATES

Core Area: Coastal Agriculture

Background

The use of weather and climate information by the agricultural industry is wide-ranging and can be generalized beyond the coastal zone. The needs of farmers for weather and climate information are derived from which crops or even livestock are being raised and where these activities are taking place. Climate, specifically the seasonal patterns of temperature and precipitation, is the primary determinant for which crops can be grown in a particular location. Other physical factors, such as soil type and topography, and cultural practices, such as irrigation or proximity to markets also influence the resulting agricultural patterns. El Niño-Southern Oscillation (ENSO) phase can significantly influence agricultural yields as well as the geographical extent of various fruit, vegetable, and non-food crops (e.g., cotton and tobacco) across the southeastern United States. For Florida, in particular, yields were lower and prices were often higher during El Niño than in neutral or La Niña winters (Hansen et al. 1999). The influence of ENSO on crop production in the southeastern United States identified crops that are vulnerable to ENSO-related weather variability and therefore likely to have important implications for both producers and consumers from application of ENSO-based climatologies. The results highlight the critical role of climate and production-related data on station or county levels in quantifying the impact of ENSO climate anomalies on yields.

Due to higher specific heat and transport of energy from the tropics, coastal zones in the southeast United States can experience climatic conditions that are more favorable to certain crops that would otherwise not be expected at that latitude. Along the southeastern United States Atlantic coast, maritime air can moderate the thermal regime allowing for the northward planting of fruits and vegetables. Figure 1 shows Plant Hardiness Zones for the southeastern United States that are based on the average annual minimum temperature. Instead of tracking parallel to lines of latitude, these Zones track parallel to coastlines of the southeast Atlantic coast. By comparing coastal locations with inland locations within the same Hardiness Zone, the moderating effect of maritime air can be illustrated (Table 1). A generalization might conclude that along the Southeast Atlantic coast, the maritime influence on air temperature and growing season is equivalent to an increase of *one* Hardiness Zone.

Agriculture in hardiness zones that have migrated northward based on average conditions may be a double-edged sword. Multiple rotations during a growing season can allow for greater annual productivity. Cultivation of crops not typically grown at that latitude may be possible because of warmer temperature. In either case, extreme weather that is not as common in lower latitude, such as frosts, may affect agricultural activities in maritime-modified hardiness zones.

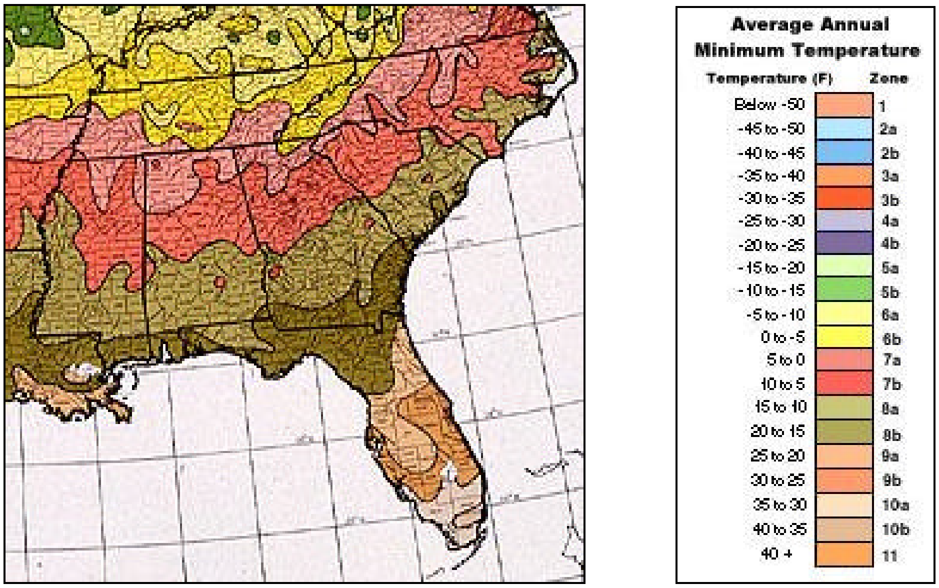

Figure 1 Plant hardiness zones for the southeastern United States (USDA 1990).

Table 1 USDA hardiness zones and average annual minimum temperature range for the southeastern United States (modified after USDA 1990). Latitude is taken from the primary National Weather Service first-order or cooperative weather station. *Mobile, AL is within a coastal zone, but it is at least 320 km south of Charleston, SC.

Zone	Temperature (ºC)	Coastal Location	Latitude	Inland Location	Latitude
7a	-15.0 to -17.7	—	—	Richmond, VA	37º 30' N
7b	-12.3 to -14.9	Norfolk, VA	36º 54' N	Atlanta, GA	33º 38' N
8a	-9.5 to -12.2	Wilmington, NC	34º 16' N	Montgomery, AL	32º 18' N
8b	-6.7 to -9.4	Charleston, SC	32º 54' N	*Mobile, AL	30º 41' N
9a	-3.9 to -6.6	St. Augustine, FL	29º 53' N	—	—
9b	-1.2 to -3.8	Fort Pierce, FL	27º 30' N	—	—
10a	1.6 to -1.1	Naples, FL	26º 09' N	—	—
10b	4.4 to 1.7	Miami, FL	25º 47' N	—	—

Problem statement: coastal agricultural pest forecasting

In addition to moderating thermal climates of coastal zones, marine air may also serve to provide moisture to the region in the form of precipitation, dew, or fog. Although adequate precipitation is necessary to meet the needs of crops, moist environments may also promote the growth and spread of plant disease. We will illustrate the use of climate data and weather forecasts to predict the spread of plant disease, namely Downy Mildew. Downy Mildew is a foliar (leaf) disease that is caused by the fungus *Pseudoperonospora cubensis*. This disease reduces yields, decreases fruit quality, and in severe cases kills plants of most cucurbits such as squash, cucumbers, pumpkins, and cantaloupes. This disease draws the attention of farmers and extension agents because the fungus develops and produces spores in one location and are transported and deposited to other locations by wind. Several weather factors are important during each stage of disease development. Four stages of disease development are sporulation, transportation, deposition, and infection. Holmes and Main (2003) developed a cucurbit Downy Mildew forecast that considers weather factors at each stage of development. The forecast provides outlooks of disease risk, descriptions of source areas, and maps of likely atmospheric trajectories away from a source area.

First, the location and features of sporulation or the release of spores into the atmosphere must be identified. If crops are infected, they should be treated with fungicide. Optimal weather conditions for sporulation are a combination of high atmospheric and near-surface moisture conditions (nocturnal relative humidity (RH) > 95% for 2 hours, 15ºC = temperature = 25ºC, and = 6 hours of dew). However, RH needs to decrease while temperatures increase to commence the release of spores. Sporulation is commonly associated with recent rainfall or irrigation and foggy mornings, although persistent rainfall can decrease spore release or cause atmospheric washout. Sporulation typically occurs during the night with release between 8 AM and 1 PM. Although daily rainfall and temperature are widely available, hourly temperatures and relative humidity are typically found at airport weather stations or increasingly at automated agricultural weather stations.

The Downy Mildew forecast estimates the transport and survival of spores away from a source location. Since exposure to ultra-violet radiation and low humidity will desiccate the spores, transport forecasts consider the amount of cloud cover and atmospheric humidity as well as the trajectory of atmospheric flow. Figure 2 shows the expected horizontal path of spores and the vertical motion (lower pane) after they are released into the atmosphere. Trajectory forecasts typically begin at 10 AM to coincide with maximum spore release. Although spores are assumed to be near the center of the trajectory, the spore cloud will spread away from the center and potentially impact areas on either side of the trajectory (Keever *et al.* 1998). Observations of cloudiness and measurements of atmospheric humidity are typically available at airport locations or locations with vertical atmospheric profile systems.

The next step in the Downy Mildew forecast is the estimation of spore deposition along the expected trajectory. The key weather element is the location, duration, and intensity of precipitation. Spore deposition is based on the probability of precipitation along the expected trajectory, including the timing of precipitation (before, during, or after passage of the spores), the location of precipitation (spores rained out before reaching production areas), and the nature of precipitation (thunderstorms or widespread light rain). Monitoring weather conditions may provide early warnings for disease potential.

Once deposition of spores has been estimated, the chance of infection in exposed cucurbit locations is estimated. Optimal weather conditions for infection are mild temperatures and high moisture conditions (15ºC = temperature = 25ºC, and = 2 hours of dew). Within this temperature range, the presence of fog, daytime cloudiness, and precipitation will provide conditions favorable to infection. "Dew is also a provider of free moisture, but typically is not considered because: (1) it is a "local conditions" phenomenon not usually mentioned in available weather forecasts, and (2) the scenarios in which it may be more important than fog or rain are rare." If trajectory and atmospheric characteristics were favorable for spore deposition then the local weather conditions would provide guidance as to the appropriateness of early abatement procedures.

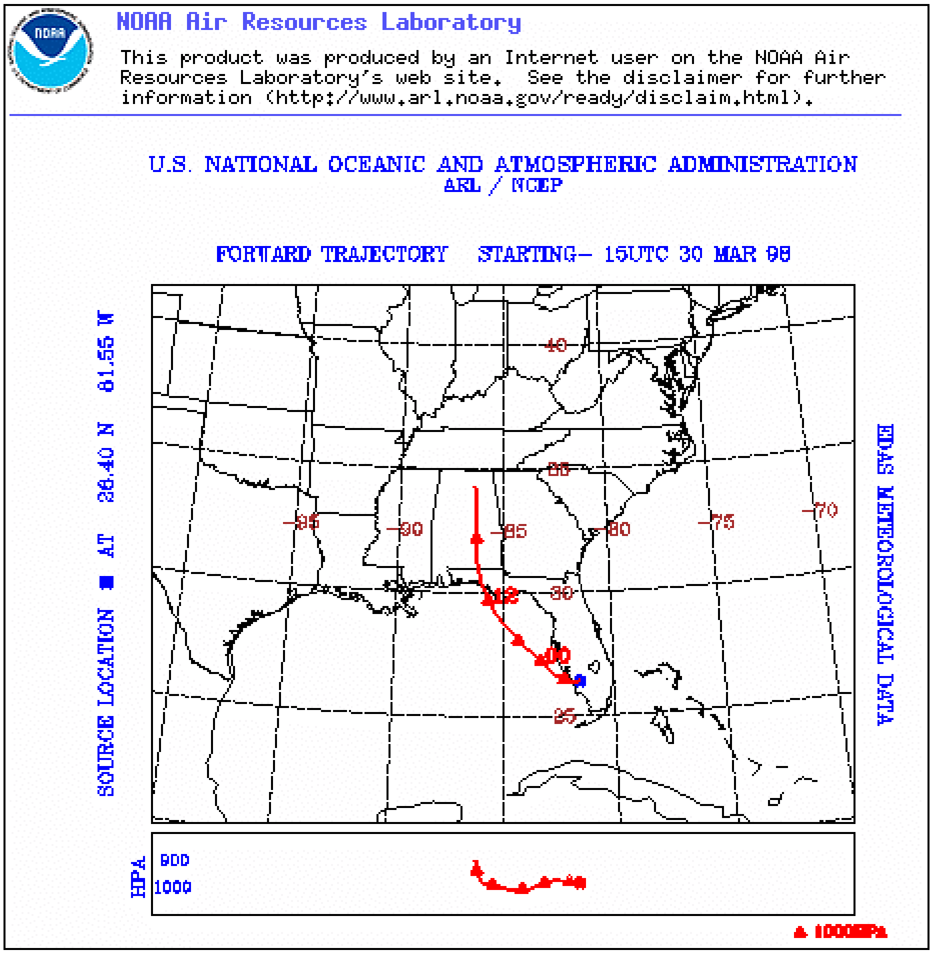

Figure 2 Expected horizontal and vertical motion of a particle released at 10:00 AM on March 30, 1998 from Immokalee, FL (Keever *et al.* 1998). Triangular markers on both panes correspond to particle location at 6-hourly time increments.

Table 2 Summary descriptions of data needs, access information, relative costs and quality for a coastal agricultural pest-forecasting product.

DATA OR PRODUCT	SOURCES	ACCESS	COST	QUALITY/WEAKNESS
Hourly relative humidity, temperature, precipitation	NOAA NWS, NCDC, RCC other mesonetworks, USDA	Internet	Real-time free Archive $	Somewhat limited spatial coverage
Hourly weather observations: fog, cloudiness	Real-time NOAA NWS	Internet	Free	Time intensive
	Archive NOAA NCDC RCC	Internet	$	Somewhat limited spatial coverage
Hourly leaf wetness	Limited to local mesonetworks and research networks	N/A	N/A	Limited availability
Trajectory forecast, including cloud cover and atmospheric humidity	NOAA ARL	Internet	Free	Requires highly skilled end-user
Radar precipitation	Real-time NOAA NWS	Internet, satellite	Free, third-party subscription	Data intensive
	Archive NOAA NCDC	Internet	$$	Data intensive

Enumeration of resources and logistics for integration of weather, climate, and marine information in coastal agriculture

1) Data and analytical tools needed to produce the product.
   - Hourly temperature, precipitation, humidity, leaf wetness (dew), wind speed, wind direction, and fog observations near coastal agricultural areas. Some measurements may be interpolated over distances of 10 km (e.g., wind) while others are more suited for very near the measurement location (e.g., leaf wellness, soil moisture).
   - Short-term freeze prediction.
   - Seasonal drought prediction and monitoring.
   - El Niño/La Niña predictions. ENSO-related seasonal precipitation forecasts would be beneficial for estimating ENSO-related yield deviations if details are provided on predicted changes in temporal and spatial variability of climate (Legler *et al.* 1999).
   - Rainfall climatology based upon radar and ground measures that focus upon the impact of the sea breeze on coastal rainfall.

2) Source for the data and analytical tools and cost and suitability to core area.
   - NOAA:
     ? National Weather Service Local Forecast Offices **http://www.nws.noaa.gov/organization.html**
     ? National Hurricane Center **http://www.nhc.noaa.gov/**
     ? National Climate Data Center **http://www.ncdc.noaa.gov/oa/ncdc.html**
     ? Air Resources Laboratory **http://www.arl.noaa.gov/**
     ? Regional Climate Centers **http://www.nrcc.cornell.edu/other_rcc.html**

- United States Department of Agriculture and NOAA Joint Weather Facility **http://www.usda.gov/agency/oce/waob/jawf/index.html**
- State Climatology Offices **http://www.ncdc.noaa.gov/oa/climate/stateclimatologists.html**
- Participants indicated that access to free data and analytical tools is one of, if not the most important motivating feature in product selection. Therefore, the majority of data and analytical tools that they utilize are an amalgamation of low cost/free offerings.

3) Present format of data and analytical tools and any changes needed.
   - Hourly and daily near-real time weather observations are available through NOAA data providers in standard ASCII formats. Metadata such as geographical coordinates are readily available.
   - Short-term weather, seasonal climate, and tropical storm forecasts are available in text formats over the Internet or via satellite. Some of these products are in ASCII format while others are textual.
   - Radar products are available for many different time increments, such as 5-10 minute intervals, hourly precipitation totals, and storm total precipitation. Spatial resolution of these products may be as fine as 1.1 nautical mile grids.

4) Accessibility of the data.
   - Climate and weather data are easily accessed by farmers and agricultural managers. Accessibility of the weather and climate data can be improved through the following means:
     ? Provide both hard copy and digital data.
     ? Existing weather radio reports for agriculture can be improved.
     ? All data must be able to be personalized to the end user. Web sites should have options for graphics, text, model analyses etc.
   - Maddox *et al*. (2003) found that personal and printed communication sources were preferred over electronic communication sources for those seeking agricultural [and weather] information.

5) Gaps or weaknesses in current data, products, tools, or providers.
   - More soil moisture and soil temperature observations, including hourly measurement intervals, vertical profiles measurements, several sensors per county, and access to near-real time and historical data. Currently, there are fewer than 200 soil moisture and soil temperature monitoring locations in the contiguous United States and only a small percentage of these are in coastal zones.
   - More photosynthetic active radiation or solar radiation measurements, including hourly measurement intervals, several sensors per county, and access to near-real time and historical data.
   - More evaporation measurements or weather systems capable of evaporation modeling, including hourly intervals, several sensors per county, and access to near-real time and historical data.
   - Would like to see continued improvement in skill seasonal climate forecasts.
   - Dew forecasts and observations are not widely available.

6) Cultural, educational, and institutional obstacles.
   - Competition between private and public sector to provide data.
   - Different quality control standards between entities collecting data.
   - Historically weak political climate for funding research in support of agriculture, although recent droughts have provided a resurgence of interest.
   - Potential computer and technology skills limitations of end-users.
   - Development of effective partnerships between organizations to manage and monitor resources, organizations that regulate, and the end users. Potential confusion about inherently government services versus private sector services. Questions on competing or redundant agency missions, policies, and institutions.

7) Training for coastal climatology end-users.
   - People making the decisions are not trained to interpret data or models.
   - Planners/engineers need a tool to connect effectively with commissioners and managers.
   - Visualization tools needed.
   - Provide training modules for specific user groups (e.g., Future Farmers of America, tobacco farmers, Hispanic migrant workers). Training for NPS pollution, for example, might include the use of irrigation schedules for water consumption and optimal conditions for pesticide applications. Training levels should be geared to a user group's level of knowledge and complexity of integration.
   - Provide funding for K-12 education component for students and teachers and collaborate outreach with existing agencies to provide training (i.e. Sea Grant, Cooperative Extension).
   - Ensure media involvement to provide advertising and publicity for coastal climatology product.

Core Area: Coastal Energy Conservation and Planning

Background

The use of weather and climate information by the energy industry is extensive and multidimensional. It is extensive because nearly every stage of energy production and delivery is sensitive to weather or climate. Energy demands of residential and commercial buildings are the largest end-user of electricity in the United States, consuming 62% of electricity generated in 1989 (NAS 1992). Within these buildings, approximately 47% of electricity consumption consists of space heating and cooling (NAS 1992). With projected increase in the coastal population of the United States, residential and commercial building energy demands will likely increase. Given that the indoor-to-outdoor temperature differential is one of the driving forces in heating and cooling energy demand (Markus and Morris 1980), an increased knowledge of coastal climatology will assist coastal energy managers meet this increased demand. Daily air temperature is the primary control of residential energy demand. Further, hydrologic generation of power is dependent on the availability and variability of water resources. The security and stability of power transmission is dependent on severe weather forecasting, preparedness, and recovery. In addition, disastrous weather events can cause considerable damage to energy transmission infrastructure. Saffir (1991) noted, after Hurricane Hugo, that utility companies in South Carolina and the Caribbean had not given "sufficient consideration" to planning for damage from a hurricane. Further a recommendation was proposed that utility companies need to develop hurricane resistant criteria for design and planning for energy transmission lines.

We describe the use of weather and climate information in energy as multidimensional because different components of power generation have different weather and climate sensitivities. Since power delivery is a competitive market, power utilities need to understand the weather sensitivities of others within the regional as well as the climatic variability that is occurring across the continent. Deregulation of power utilities places even more emphasis on delivery of climatic information and forecasts because of the diverse and competitive nature of power management. Energy production from different fuels (e.g., coal, nuclear, gas, water) is rooted in supplying electricity to consumers for profit. Though each fuel-based method has similar objectives and similar transmission infrastructure, they often have very different geologic, economic, and atmospheric sensitivities.

Although the energy sector is one of the biggest users of weather and climate information, Altalo *et al*. (2000) found that the wide-scale use of weather and climate information in the energy industry is impeded by several factors. These factors include product problems such as low geographic and temporal resolution, limited parameters, and lack of data continuity; and interpretation problems such as lack of direct communication between the suppliers of information (e.g., meteorologists) and the users of information, and poor assimilation and integration of data into decision-making processes. The use of weather and climate information was found to be more diverse between large and small utilities than across different sectors or across different regions. In general, large energy utilities have more sophisticated integration of weather and climate information into decision making and planning. Hydroelectric power shares many management decisions with other energy producers (i.e., transmission and load forecasting), but it has the unique task of managing reservoirs. Because there are unique features of hydroelectric power management within the coastal zone, we will describe the weather and climate information needs associated with these decisions.

Problem statement: hydroelectric power generation and reservoir management

Workshop participants identified major components of any hydropower systems that are sensitive to weather or climate conditions. These components are

1. Identifying a suitable location for hydroelectric power generation – long term,
2. Load planning for energy distribution area – short term,
3. Water resource planning and management – short to midterm,
4. Transmission planning for pricing – mid to long term.

Identifying suitable locations for hydropower generation involves complex studies of the underlying geological structures as well as geophysical modeling of filled reservoirs. Considerations for environmental, economic, and cultural impacts are weighed against the beneficial aspects of dam and reservoir construction and management. Compared with these factors, weather and climate play a small role in identifying suitable locations for hydropower generation. Nevertheless, long-term precipitation, stream flow, and runoff regimes provide information on the availability of water. Long-term temperature approximates water loss by evaporation. Although long-term averages are important, daily, seasonal, annual, and decadal patterns of these parameters provide information on the expected ranges of water availability as well as important periodicities or severe events such as floods and droughts. Decision making for locating hydropower plants is complex and based on in-depth physical and economic studies and models. It is generally beyond the scope of uses of weather and climate in hydropower operations.

Load forecasting, or predicting the short-term (less than 10 days) consumer energy demand, requires a different set of meteorological parameters and products. Cultural forces such as day-of-the-week and consumer type (residential or commercial) typically drive the demand for energy. The ability to supply energy on demand depends on the amount of water in the reservoir, the amount of water entering the reservoir, and the flow out of the reservoir. Decisions on instantaneous supply of hydroelectricity also depend on the projected energy demand (10-days to one month) and the estimation that the system could meet that demand. Weather forecasts that predict temperatures 10-days in advance support load planning (although forecast skill currently diminishes after about 5 days). Temperature is the primary weather element affecting energy demand. For residential consumers, the demand for heating and cooling energy increases as temperatures deviate from 18ºC. Hackney (2003) found that the economic value for accurate temperature forecasts increased greatly for temperature 5.5ºC greater or less than 18ºC. Energy producers would plan for power generation to meet temperature-based demand 10 days in advance. Forecasts for other variables that affect heating or cooling demand are precipitation, cloud cover, wind speed, and humidity. Since air conditioning also provides humidity control, incorporating humidity forecasts in load planning may be more important than previously recognized, especially in the southeast United States. Demand forecasts often rely on the ability to predict weather across a service area from several hours out to several weeks. These forecasts allow energy utilities to determine the best and most cost-efficient mix of power generation to meet electricity load demands (Altalo *et al*. 2000). Energy utilities often have multiple types of power generation, such as hydroelectric, nuclear, or gas and optimize the use of different types based on overhead cost, demand, and revenue.

Load planning and managing water resources are inseparable since water availability is essentially the fuel for power generation. For example, minimum and maximum flow, defined at the time an energy project is licensed, regulate the flow of water out of the reservoir. Maintaining minimum flow may be a competing management decision during drought conditions. Because municipal and industrial water uses along coastal river systems are sensitive to increased salinity, monitoring systems alert upstream dam operators to release water before a salt wedge reaches sensitive intakes. This water may not be available for hydroelectric power generation. Other competing uses for reservoirs, such as flood control, recreation, irrigation, fishing, and lakeshore living have a factor in managing the water supply. Hydroelectric operations use precipitation and stream flow measurements upstream from the reservoir to estimate input of water into the reservoir. Ongoing hourly precipitation and stream flow measurements are combined with precipitation forecasts for the upstream basin to estimate power output 10 days in advance. Modified stream flow models may incorporate local and basin conditions and require the input of local precipitation, wind, temperature, humidity, and solar radiation data (Altalo *et al*. 2000). Coastal hydropower operations often have an additional management requirement to flush a salt-water wedge from downstream locations.

Long-range planning and pricing for transmission and demand requires accurate monthly and seasonal climate forecasts. Hydropower operators can factor seasonal forecasts into water management decisions. For example, seasonal forecasts for above normal temperatures and below normal precipitation translate into greater energy demand and less water supply. A potential management decision would be to increase reservoir levels. Hydropower operators may also use seasonal forecasts to prepare for increased precipitation. By lowering reservoir levels and selling power, they could generate revenue an d prepare for potential flood conditions Because startup and shutdown of generation units and poor management of water resources is a major cost to hydropower operations, improving monthly and seasonal climate forecasts could save large utilities millions of dollars annually (Altalo *et al*. 2000).

Table 3 Summary descriptions of data needs, access information, relative costs and quality for a hydroelectric power generation and reservoir management product.

DATA OR PRODUCT	SOURCES	ACCESS	COST	QUALITY/WEAKNESS
Precipitation and stream flow climatology	NOAA NCDC, USGS	Internet, CD-ROM	$	Limited spatial coverage of gauged watersheds and bias towards large watersheds.
Real-time stream flow	USGS, NOAA NWS	Internet	Free	Limited spatial coverage of gauged watersheds and bias towards large watersheds.
Weather forecasts to 10 days	NOAA NWS	Internet	Free, third-party subscription	End-user time intensive.
Seasonal and monthly climate forecasts	NOAA CPC	Internet	Free	Generalized spatial patterns. Lower skill during some phases.
Hourly precipitation radar	Real-time NOAA NWS	Internet, satellite	Free, third-party subscription	Data intensive and difficult to format for common software (GIS).
	Archive NOAA NCDC	Internet	$$	Data intensive and difficult to format for common software (GIS).

Enumeration of resources and logistics for integration of weather, climate, and marine information in energy generation

1) Data and analytical tools needed to produce the product.
   - Information for managing reservoir:
     - ? Lake level, stream flow/runoff, precipitation, and temperature measurements in the river basin upstream from the reservoir.

    ? Salinity measurements in order to maintain integrity of river ecology and industrial uses downstream of the hydroelectric plant and dam.
    ? Forecasted precipitation to estimate stream flow and lake level. Forecasts need to be specific to reservoir.
- Information for energy transmission and load forecasting:
    ? Ten-day forecasted temperature, humidity, cloud cover, wind speed, and precipitation across the service area of the power company.
    ? Monthly seasonal climate forecasts for the service area as well as adjacent regions.

2) Source for the data and analytical tools and cost and suitability to core area.
    - NOAA:
        ? National Weather Service Local Forecast Offices **http://www.nws.noaa.gov/organization.html**
        ? National Hurricane Center **http://www.nhc.noaa.gov/**
        ? National Climate Data Center **http://www.ncdc.noaa.gov/oa/ncdc.html**
        ? Climate Prediction Center **http://www.cpc.ncep.noaa.gov/**
        ? Regional Climate Centers **http://www.nrcc.cornell.edu/other_rcc.html**
    - United States Geologic Survey, Water Resources Division **http://water.usgs.gov/**
    - State Climatology Offices **http://www.ncdc.noaa.gov/oa/climate/stateclimatologists.html**
    - Participants indicated that access to free data and analytical tools is one of, if not the most important motivating feature in product selection. Therefore, the majority of data and analytical tools that they utilize are an amalgamation of low cost/free offerings.

3) Present format of data and analytical tools and any changes needed.
    - Hourly and daily near-real time weather observations are available through NOAA data providers in standard ASCII formats. Metadata such as geographical coordinates are readily available.
    - Short-term weather, seasonal climate, and tropical storm forecasts are available in text formats over the Internet or via satellite. Some of these products are in ASCII format while others are textual.
    - Radar products are available for many different time increments, such as 5-10 minute intervals, hourly precipitation totals, and storm total precipitation. Spatial resolution of these products may be as fine as 1.1 nautical mile grids.

4) Accessibility of the data.
    - Large energy companies often have their own climatology, meteorology, and hydrology sections that extract data from NOAA weather stations or their own networks and create their own products. Private companies often provide software and analysis to small to mid-sized energy companies.
    - Climate and weather data are easily accessed by energy managers. Data provided over the Internet is preferred over other formats. However, the accessibility of the weather and climate data can be improved through the following means:
        ? Scientific websites are often not in the format of or easily understood by end-users.

   ? The ideal format for energy manager access to coastal climatology products is "through a dynamic, web-based system accessed by a variety of users to build and manage their customized products and solutions."

5) Gaps or weaknesses in current data, products, tools, or providers (adapted from Altalo *et al*. 2000).
   - Recommended improvements in forecast products:
     - ? Greater accuracy of weather and climate forecasting, including increased spatial and temporal resolution.
     - ? Standard method for expressing the confidence level of forecasts.
     - ? Five to ten-day hourly forecasts on atmospheric conditions
   - Recommended improvements for observational data:
     - ? Better availability, longer time periods, improved continuity of historical time series.
     - ? Improved standardization between geographic locations, including electronic reporting formats and near-real time reporting.
     - ? Additional weather stations in energy strategic location.
     - ? Real time wind data to allow for dispatch of maintenance crews to repair downed power transmission lines. Repair of power lines should occur as soon as possible, but not while weather conditions are dangerous or may cause additional damage.
     - ? Radar product that delineates between rain and ice.
   - Recommended improvements in blended or derived products:
     - ? Integrated rainfall by small river sub-basins for river flow analysis.
     - ? Hourly average heating and cooling degree calculations by NOAA in place of daily high/low averages currently provided.

6) Cultural, educational, and institutional obstacles.
   - Lack of consensus among scientific community in interpretation of results and utility of a product.
   - Potential computer and technology skills limitations of end-users.
   - Development of effective partnerships between organizations to manage and monitor resources, organizations that regulate, and the end users. Potential confusion about inherently government services versus private sector services. Questions on competing or redundant agency missions, policies, and institutions.

7) Training for coastal climatology end-users.
   - Provide training modules for specific user groups (e.g., regional power associations, electric cooperatives). Training for load planning for energy distribution area, for example, might include the use of weekly and seasonal forecasts for water consumption and optimal conditions for energy generation. Training levels should be geared to a user group's level of knowledge and complexity of integration.
   - Provide funding for K-12 education component for students and teachers and collaborate outreach with existing agencies to provide training (i.e. Sea Grant, Cooperative Extension).
   - Ensure media involvement to provide advertising and publicity for coastal climatology product.

Core Area: Coastal Environmental Quality

Background

Many coastal communities were founded as regional ports to support trade, shipping, and fisheries and sea-borne commerce often continues as the primary economic activity of those communities. In the United States, 93% of international trade, one billion tons of cargo valued at $500 billion, moves in and out of U.S. deep draft ports (CMMF 1994). Given the importance of such economic activities, maintenance of ports, harbors, intra-coastal waterways and other navigational infrastructure is of paramount importance to maintaining the economic vitality of a coastal community. Natural coastal processes, such as tides, ocean currents, waves and sedimentation can cause the degradation of navigation and sea-borne commerce infrastructure (Pilkey and Dixon 1996). Such degradation takes the form of infilling navigational channels and shoaling in harbor or port entrances. In response, coastal communities have implemented dredging projects to clear navigational channels and harbor/port entrances.

The United States Army Corps of Engineers (USACE) has the primary responsibility for the construction and maintenance of navigational infrastructure in Federal waters. The societal benefits of USACE coastal dredging, improved navigation infrastructure, material for beach nourishment, land development, offshore mound and island construction, creation of agricultural land, supply of construction aggregate, and enhancement of wetlands and aquatic and wildlife habitats has long been recognized (Engler 1990). However, since the increase in environmental awareness of the 1960s and 1970s, negative impacts of coastal dredging have also been documented (Truitt 1988). This concern lead to the promulgation of over 30 Federal environmental statutes, Executive Orders, and Government regulations, particularly, Section 103 of the Marine Protection, Research, and Sanctuaries Act of 1972 (MRPA) and Section 404 of the Clean Water Act of 1977 (CWA), to regulate dredge activity and dredge material disposal (Walls *et al*. 1994). Of particular concern to environmental quality is the disposal of dredge material. Estimates indicate that on a global scale, disposal of dredge material is the largest input of waste material to the ocean on a mass basis (Kester *et al*. 1983). The USACE dredges over 250 million m^3 of sediment per year to maintain more than 30,000 km of waterways and about 1000 harbor projects (ASCE 1983). The environmental degradation created by dredged material can be linked to two specific factors, the dredge material itself and the fate of the dredge material once it has been placed at a disposal site.

The physical and chemical characteristics of the dredge material can be negative to the surrounding environment through heavy metal, petroleum hydrocarbon and synthetic organic chemical contamination (Kennish 1997). The reason for this contamination is that navigational lanes represent areas with a high degree of exposure to industrial materials and activities, causing a high degree of chemical pollution. However, it has been noted that the industrially contaminated sediments only comprise 10% of the dredged material (Engler 1990). Environmental degradation can be created by ‘natural’ or uncontaminated sediments due to high proportions of clay and organic material. The high proportion of clay many times represents a change in sediment grain size at the disposal sight that can impact benthic organism populations and diversity and a high degree of organic material may result in anoxic conditions that can be detrimental to benthic fauna development (Kester *et al*. 1983).

The fate of the dredged material is important because sediments that are not retained at the disposal site can cause an increase in water column turbidity, burial of benthic organisms, and leachate contamination (Wright 1978). The increased water column turbidity can interfere with pelagic organism population dynamics and biogeochemical marine cycles. The burial of benthic organisms is another avenue of reducing benthic organism populations and their diversity. Leachate contamination can take many forms depending upon the type of disposal site under consideration. In open water disposal sites, changes in redox potential and pH of sediments over time may cause metals to be released in solution above the disposal site (Kestler *et al*. 1983). For upland disposal sites, sediments with high sulfide content can lead, after several months of drying and oxidation, to acid conditions and metal leaching to overland flow and groundwater (Engler 1990).

Given the broad array of environmental degradation that can result from introduction of dredge material to an environment, a wide variety of dredge disposal strategies have been developed and applied to minimize negative environmental impacts to coastal regions. These strategies can be divided into subaerial, upland disposal, and subaqeous, open-water disposal (Herbich 1981; Kennish 1997; Kester *et al*. 1983). Types of upland disposal include dike-weir systems for land application, landfill for shoreline modification, wetland application, and construction of artificial island. Types of open-water disposal include seafloor mounds and subaqeous burrow pits (capped and non-capped). Successful implementation and management of these different disposal strategies relies upon proper assessment of the dredge material itself and the disposal site environment. This initial environmental assessment (EA), as mandated by the MRPA, the CWA and the National Environmental Policy Act (NEPA), documents if the proposed activity will create any significant environmental impacts (ELI 2002). If the EA indicates no significant environmental impact is anticipated a finding of no significant impact (FONSI) is prepared. If the EA indicates that there may be some environmental impact, analysis is completed to prepare an environmental impact statement (EIS). The EIS/FONSI can contain an assessment of the impacts on existing environmental quality, impacts on water quality, critical habitat losses, impacts on environments adjacent to candidate sites, impact on material cycles, impacts on migration and movement patterns, impacts on groundwater resources, impacts on cultural resources, and impacts on human uses (Holland *et al*. 1993). Once such assessment has been completed, a permit for dredging can be issued through the USACE, and a balance between both the positive and negative impacts of a project is achieved.

Problem statement: open-water seafloor mound dredge material disposal

The most important aspect of the dredge and dredge material disposal process pertaining to environmental quality is the development of an EA. An EA indicates whether the potential for undue environmental degradation exists due to the dredge project and represents a coastal community's best tool for balancing the economic benefits against potential environmental degradation. Integrating climate data into assessments would increase their robustness (Holliday 1978). This section will outline the issues associated with the task of incorporating climate data into an EA for an open-water seafloor disposal mound. Open-water seafloor mound dredge disposal entails the dumping of dredge material, usually by a barge, onto the seafloor, forming mounds. Typically, the dumping occurs offshore in deeper water (30 to 200m) where interference from shipping and fishing activities is negligible (Herbich 1981). The reason for focusing upon this specific type of dredge disposal activity is that those workshop participants associated with dredging activities were directly involved in seafloor mound dredge disposal site assessment. The information provided by workshop sessions best reflects the application of climate data to this type of disposal site.

The general steps in completing a EA for a seafloor mound dredge material disposal are determination of existing data available for site assessment, establishment of monitoring program to generate additional data required for site assessment, and predictive analysis of all data for site assessment (usually this entails the use of a numeric model) (Holliday, 1978). The types of data required for site assessment can be placed into three broad classes, biological information, physical and chemical information, and hydrodynamic information (Moore *et al*.1998). Climate data are classified as hydrodynamic information; current velocity, current depth profiles, wave exposure, wind fetch, duration, and direction, seasonal salinity and temperature profiles, local tidal ranges, and storm probability and track (tropical and extra-tropical). Though many of these variables fall outside the realm of traditional climate data, as indicated at the beginning of this report, climate was defined by many coastal officials as a hybrid or integration of oceanographic and climate processes. The use of this information applies primarily to the fate of dredge materials at the disposal site. Through the climatic/oceanographic data, the dispersal of dredge materials to the surrounding water column and ocean floor after dumping, can be determined. Based upon this dispersal assessment and the purpose of the disposal site, undue negative environmental impacts at the disposal site can be identified.

Further, MRPA requires the United States Environmental Protection Agency (EPA) and the USACE to manage and monitor a disposal site once it has been established. These activities are governed by the site management and monitoring plan (SMMP) that outlines disposal site characteristics, management objectives, material volumes, material suitability, time of disposal, disposal technique, disposal location, permit and contract conditions, baseline monitoring, disposal monitoring, post discharge monitoring, material tracking, and disposal effects monitoring (USEPA and USACE 2000). The monitoring and management activities rely heavily upon surveys and studies that include climatic and oceanographic variables to indicate the potential movement and environmental degradation. As can be seen on Figure 3, the geographic range of dredge disposal sites in the southeastern United States creates the need for a variety of data from multiple locations to monitor the different coastal environments represented by each site.

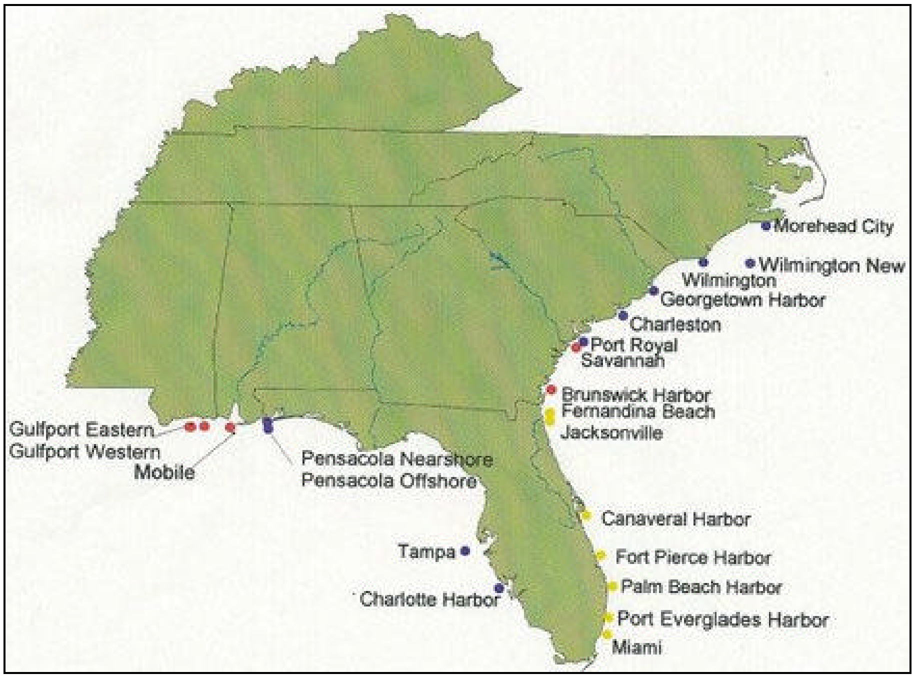

Figure 3 Location of open water dredge disposal sites within United States Environmental Protection Agency, Region 4 coastal waters. Colored dots represent different project managers in US EPA, Region 4 Oceans and Coastal Program (Source http://www.epa.gov/region4/water/oceans/sitesmap.htm)

Table 4 Summary descriptions of data needs, access information, relative costs and quality for open-water seafloor mound dredge material disposal.

DATA OR PRODUCT	SOURCES	ACCESS	COST	QUALITY/WEAKNESS
Sea level trends	NOAA NOS CO-OPS	Internet	Free	Limited locations for which data is available.
Wave climatology	Ocean Weather Inc., NOAA NBDC C-MAN	Internet	Free, $$	Limited locations for which data is available, assumptions of gridding interpolation algorithms.
Real-time waves, currents, water levels, weather conditions from buoy or pier site	NOAA NDBC, Ocean Weather Inc., Buoyweather.com, Weather Underground, NCEP, FNMOC	Internet	Free, $$	Location of buoys away from study area and poor spatial resolution of buoy network.
Seasonal and monthly climate forecasts	NOAA CPC	Internet	Free	Generalized spatial patterns. Lower skill during some phases.
Tropical storm forecasts	NOAA NHC	Internet, satellite	Free, third-party subscription	Short lead-time of forecasts and user's low confidence in accuracy.
Tides	NOAA NOS CO- OPS	Internet	Free	Limited locations for which data are available

Enumeration of resources and logistics for integration of weather, climate, and marine information in open-water dredge material disposal

1) Data and analytical tools needed to produce the product.
   - Ocean current location and velocity (1 m off ocean floor), recorded at a variety of time scales in order to assess the complete range of current conditions at the disposal site.
   - Wave-length, height, and duration near disposal site, recorded at a variety of time scales in order to assess the complete range of wave conditions at the disposal site.
   - Diurnal or semi-diurnal tide amplitude near disposal site, recorded at a variety of time scales in order to assess the complete range of tidal conditions at the disposal site.
   - Seasonal patterns in ocean current, wave, and tide data. In particular, winter values since this is the season of greatest wave activity.
   - Numerical models to assess surface and subsurface dispersal of dredge materials. Currently, three models are commonly used for site assessment; the dump model, Disposal From Instantaneous Dump (DIFID), and the general transport models LAEMSD and STUDH (Johnson and Schroeder 1993; McAnally and Adamec 1987). However, the development of user-friendly version of such models that easily incorporates climate data would increase use in site assessment.

2) Source for the data and analytical tools and cost and suitability to core area.
   - NOAA:
     ? National Weather Service Local Forecast Offices **http://www.nws.noaa.gov/organization.html**
     ? National Hurricane Center **http://www.nhc.noaa.gov/**
     ? National Climate Data Center **http://www.ncdc.noaa.gov/oa/ncdc.html**
     ? Climate Prediction Center **http://www.cpc.ncep.noaa.gov/**
     ? Regional Climate Centers **http://www.nrcc.cornell.edu/other_rcc.html**
     ? National Ocean Service, Center for Operational Oceanographic Products and Services **http://www.co-ops.nos.noaa.gov/**
     - National Data Buoy Center **http://seaboard.ndbc.noaa.gov/index.shtml**
     ? Regional Climate Centers **http://www.nrcc.cornell.edu/other_rcc.html**
     ? NWS, NCEP Marine Modeling and Analysis Branch **http://polar.wwb.noaa.gov/**
   - Ocean Weather Incorporated **http://www.oceanweather.com/data/index.html**
   - Buoyweather.com **http://www.buoyweather.com/**
   - Weather Underground Marine Weather **http://www.wunderground.com/MAR/AM/**
   - United States Navy Fleet Numerical Meteorological and Oceanographic Center **https://www.fnmoc.navy.mil/**
   - Participants indicated that access to free data and analytical tools is one of, if not the most important motivating feature in product selection. Therefore, the majority of data and analytical tools that they utilize are an amalgamation of low cost/free offerings.

3) Present format of the data and analytical tools and any changes needed.
   - Almost all of the data currently available for assessment of dredge disposal sites are available in digital format through the Internet or FTP. This format is useful in that data can be quickly integrated into available software for analysis.

4) Accessibility of the data.
   - Weather and climate data for the assessment of dredge disposal sites are easily accessed. Forecast, near-real time, and historical data are provided over the Internet. The accessibility of the weather and climate data can be improved through the following means:
     ? Revising websites for easy navigation and minimization of scientific and technical jargon.
     ? Personalizing web sites and tools for specific uses (e.g., irrigation scheduling).
     ? Providing multiple options for data and information output, such as tables, graphs, and maps.

5) Gaps or weaknesses in current data, products, tools, or providers
   - Recommended improvements of forecast products:
     ? Development (near disposal sites) of offshore tidal prediction products.
   - Recommended improvements for observational data:
     ? Deployment of nearshore directional wave gages (ADCP).
     ? More wave height data products derived from satellite images.
     ? Improved standardization between geographic locations, including electronic reporting formats and near-real time reporting.
     ? Additional real time inshore data collection buoys that include wind and wave observations.
   - Recommended improvements in blended or derived products:
     ? Integration of surface and subsurface observations to create a water column product to assist in the prediction of dredge material dispersion from disposal site.

6) Cultural, educational, and institutional obstacles.
   - Inadequate computer and technology literacy skills of end-users.
   - Development of effective partnerships between organizations to manage and monitor resources, organizations that regulate, and the end users.
   - Untested perceptions that applying weather or climate-based management strategies is more costly than some other formulation of management decisions.

7) Training for coastal climatology end-users.
   - Build education and outreach into product and systems development. Provide training modules for specific user groups (e.g., state fish and wildlife officers and local public health officials), and bring training resources to the specific user groups.
   - Include funding for education and outreach with product development.
   - Collaborate with existing agencies to provide training (i.e. Sea Grant, Cooperative Extension, Environmental Protection Agency, United States Army Corps of Engineers).
   - Ensure media involvement to provide advertising and publicity for coastal climatology product.

Core Area: Coastal Fisheries Management

Background

Economic benefits of commercial and recreational fishing total approximately $40 billion per year in the United States (NRC 1999). The economic contribution of specific fisheries varies annually due to the annual variation in species catch. The cause of such fluctuations in fish populations is a combination of economic and environmental factors. Economic factors can include relative price paid for fish, and changes in fishing methods or fishing effort, while environmental factors can include ocean circulation, ocean temperature and salinity, ocean nutrient levels and climatic variability. One example of the combination of economic and environmental factors upon fish stocks is the decline of the northern cod in the 1990's. The population of northern cod in the northeastern Atlantic Ocean declined due to over fishing and severe cold temperatures that slowed growth rates and reduced size-at-age (Drinkwater 2002). One of the challenges to commercial fisheries managers is to separate the impacts of economic and environmental factors on fisheries population. Through the separation of such factors, more effective management plans can be created.

Over the last 30 years, a fair amount of research has investigated the links between climate and climatic variability to fish population dynamics and fisheries management (e.g., Cushing 1982; Dow 1977; Laevatsu 1993; McGinn 2002). Such work has demonstrated the variety of climate-fisheries linkages at multiple locations across the United States due to different combinations of shoreline configuration, ocean currents, and dominant synoptic weather systems. Case studies have been an important tool for determining linkages between climate and fisheries in the southeastern United States. Most case studies linking climatic variability to species population dynamics and fisheries management has been completed for Alaska, New England, and Pacific fisheries. This is likely due to the location of the largest and most economically valuable fisheries in the United States (McHugh 1984). Accordingly, a search of the Web-based Cambridge Scientific Abstracts' Aquatic Sciences and Fisheries Abstracts of the most recent 100 (2002-2003) climate-fisheries related research articles provided no case studies of fisheries in the southeastern United States. Such a paucity of readily available research underscores the challenge of incorporating coastal climatology into fisheries management in the southeastern United States; information regarding climate and climate variability impact upon fisheries within the region is difficult to find.

Problem statement: integration of climate-fisheries interaction research into fisheries management

One of the difficulties in management of fisheries is the integration of environmental data into the decision-making process to allow for more efficient and sustainable management of fishery stocks (Jennings *et al.* 2001; NRC 1999). Although climate-fishery interactions have been completed, they are "seldom put to practical use in planning and management" (Regier 1977, p. 139). Despite recent advances in fisheries science, baseline information on environmental characteristics of fisheries communities has not been thoroughly described (Hart and Reynolds 2002). Thus, changes in these conditions due to climatic change or other factors may be difficult to ascribe. Anecdotally, one workshop participant commented that climate experts exist and fisheries experts exist but rarely interact, suggesting that basic research of climate-fisheries interaction in the southeastern United States is insufficient but attainable.

Despite the perception of an absence of climate and fisheries research, a few studies illustrate the potential for research of climate interaction with fisheries. For example, Parker and Dixon (2002) completed a repeat survey (1990 and 1992) of reef fauna to assess response to changes in water temperatures at 210 Rock, a sandstone and limestone ledge outcrop 44km south of Beaufort Inlet, NC. The study indicated that after 15 years of intense fishing, recreational and commercial fisheries were smaller and large changes occurred in relative abundance; specifically, species composition became more tropical (29 new tropical reef species were observed and 28 tropical species increased and a tropical sponge previously unrecorded off the North Carolina coast became common). The species composition suggests warming of regional water temperatures that was supported by observed mean winter monthly water temperatures 1-6^{o}C warmer than previous measurements. The authors believed the increase in water temperatures at the study site could be linked to warmer water along the subtidal continental shelf off Beaufort, NC.

Another example of research of climate-fisheries linkages in the southeastern United States is the research of environmental conditions associated with fish populations in the Charleston Bump, a complex bottom feature of great topographic relief located 130-1900km southeast of Charleston, SC (Sedberry *et al*. 2001). This feature deflects the Gulf Stream offshore in the South Atlantic Bight, and establishes permanent and temporary eddies, gyres, and associated upwelling in the warm Gulf Stream flow. The thermal fronts associated with the deflection are believed to attract large pelagic fish and their prey. Statistical analysis indicates that in the area of the Bump, sea surface temperatures (SST) influenced by the deflection have a role in determining recruitment success of at least one continental shelf reef fish, *Mycertopa micropelis*.

Such individual studies can be combined to provide an overview of climate change’s impact upon the southeastern United States. Mountain (2002) provided such a study that focuses upon the northern portion, Cape Hatteras to Chesapeake Bay, of the southeastern United States’ coast. In the study, he predicted that climate change in the Mid-Atlantic Bight would increase the number of warm water species, intensify seasonal stratification of water, change regional circulation, reduce reproductive success for cold water species, increase the frequency of hypoxic conditions, and create an overall northward shift in distribution of stock distributions. Further he stated that the ability to predict major responses of fish communities to short-term climatic variability, sea level rise, and elevated sea temperatures will depend on scientific interpretation of information on the rate of environmental and climatic change, fish biotic and habitat parameters, fisheries exploitation rates, and a host of other factors.

Given this need for understanding of how climatic variability affects commercial fish populations, a coastal climatology product must address potential climate-fishery habitat interaction. Perhaps, the greatest potential for development of such a product, as indicated by the results of both the Parker and Dixon (2002) and Sedberry *et al.* (2001), is assessing the relationship between ocean currents (surface and subsurface), sea surface temperature (SST) and commercial fish species variability. SST data are now available through NOAA polar orbiting satellite and additional climate variables such as air temperature, precipitation, salinity, dissolved oxygen, wind fields and hurricane intensity and frequency can be combined with the satellite data to construct a coastal climatology fisheries management tool.

However, care must be taken in developing such products. Brill and Lutcavage (2001) found that average gridded surface conditions correlated with billfish and tuna catch statistics, but did not truly evaluate the environmental conditions associated with population dynamics. Instead, these average surface conditions should be combined with depth distribution, travel speeds, forage abundance, and appropriate oceanographic data to offer a more accurate assessment of fishery population dynamics. Further, these variables need to be assessed at the appropriate scale (temporal and spatial) for the fish behavior in question. Examples of appropriate scaling include matching fish observations with simultaneous real-time oceanographic data, and the fact that vertical temperature gradients are orders of magnitude steeper than horizontal gradients and will more likely to influence movement than horizontal gradients.

The choice of appropriate scale also corresponds to management entities. Several organizations exist that regulate fisheries activities in coastal waters. For the southeastern United States, the Mid-Atlantic and South Atlantic Fisheries Management Councils (MAFMC and SAFMC) have jurisdiction within the federal 200 mile limit, while state fishery agencies, such as the South Carolina Department of Natural Resources Office of Fisheries Management, have jurisdiction in state waters. Thus, in order for effective fisheries management tools strategies to be developed in the southeastern United States, clear spatial boundaries of fish populations and associated environmental factors must be stated in order for identification of the appropriate management entity to incorporate findings into management activities.

Table 5 Summary descriptions of data needs, access information, relative costs and quality for integration of climate-fisheries interaction research into fisheries management.

DATA OR PRODUCT	SOURCES	ACCESS	COST	QUALITY/WEAKNESS
Sea level trends	NOAA NOS CO-OPS	Internet	Free	Limited locations for which data is available.
Wave climatology	Ocean Weather Inc.	Internet	Free, $$	Limited locations for which data are available, assumptions of gridding algorithms.
Real-time waves, currents, water levels, weather conditions from buoy or pier site	NOAA NDBC, Ocean Weather Inc., Buoyweather.com, Weather Underground, NCEP, FNMOC	Internet	Free, $$	Location of buoys away from study area and poor spatial resolution of buoy network.
Seasonal and monthly climate forecasts	NOAA CPC	Internet	Free	Generalized spatial patterns. Lower skill during some phases.
Tropical storm forecasts	NOAA NHC	Internet, satellite	Free, third-party subscription	Short lead-time of forecasts and user's low confidence in accuracy.
Tides	NOAA NOS CO-OPS	Internet	Free	Limited locations for which data is available

Enumeration of resources and logistics for integration of weather, climate, and marine information in near-shore commercial fisheries management

1) Specific data and analytical tools needed to produce product.
   - Limited research of climatic variability and fish populations in the southeastern United States has been used to develop fisheries management tools and strategies. Specific case studies of commercially important species in the southeastern United States (such as white shrimp, blue crabs, and oysters) need to be made available to the appropriate management entity. The analysis within these studies needs to be scale specific to the fish species behavior and management organization jurisdiction.
   - Long-term climatic variables that can be linked to fishery stock management. For instance, much research has linked SST temperature variation created by El Nino to Pacific fish population dynamics. However, it has been noted in recent research that reliance upon average gridded surface variables can lead to inaccurate assessments of fish species population dynamics. Additional information, particularly oceanographic variables in the vertical dimension or water column, need to be incorporated into analysis. In particular, movement of subsurface ocean currents and the vertical temperature gradients established by these movements is an important variable asscoated with fish movement and populations.
   - Workshop participants indicated that GIS software has some of the greatest potential for developing climate sensitive management tools and strategies. However, vertical variability of oceanographic variable needs to be integrated to traditional horizontal, or planar, GIS analysis.

2) Source for the data and analytical tools and cost and suitability to the core area.
   - NOAA
     ? National Climate Data Center **http://www.ncdc.noaa.gov/oa/ncdc.html**
     ? C-MAN Buoy Data Archive **http://seaboard.ndbc.noaa.gov/Maps/southeast_hist.shtml**
     ? National Data Buoy Center **http://seaboard.ndbc.noaa.gov/index.shtml**
     ? Regional Climate Centers **http://www.nrcc.cornell.edu/other_rcc.html**
     ? National Ocean Service, Center for Operational Oceanographic Products and Services **http://www.co-ops.nos.noaa.gov/**
     ? National Weather Service Local Forecast Offices **http://www.nws.noaa.gov/organization.html**
     ? National Hurricane Center **http://www.nhc.noaa.gov/**
     ? NWS, NCEP Marine Modeling and Analysis Branch **http://polar.wwb.noaa.gov/**
   - State Climatology Offices **http://www.ncdc.noaa.gov/oa/climate/stateclimatologists.html**
   - Ocean Weather Incorporated **http://www.oceanweather.com/data/index.html**
   - Buoyweather.com **http://www.buoyweather.com/**
   - Weather Underground Marine Weather **http://www.wunderground.com/MAR/AM/**
   - United States Navy Fleet Numerical Meteorological and Oceanographic Center **https://www.fnmoc.navy.mil/**

- Participants indicated that access to free data and analytical tools is one of, if not the most important motivating feature in product selection. Therefore, the majority of data and analytical tools that they utilize are an amalgamation of low cost/free offerings.

3) Present format of the data and analytical tools and changes needed.

- The present format of data used by fisheries management is digital format accessed through the Internet or FTP. Such formats include tab delimited and comma delimited files with and accompanying Meta data text file that explains the structure and organization of data arrays. These delimited formats are very useful for integrating data into available software, particularly spreadsheets and GIS, for analysis. Conference participants noted that fisheries managers use a wide array of data types and formats and that readily available Metadata is imperative to integrate different data sets. One suggestion was to develop a ‘Coastal Climatology Metadata Dictionary’ so that any person working with coastal climatology data can refer to such a dictionary to understand data limitations, appropriateness, and structure. Such comments indicate that efforts to develop universal standardized data formats have not been successful with the fisheries management community.

4) Accessibility of the data.

- Fisheries managers access data and analytical tools through the Internet. However, suggestions to the improvement of this accessibility by fisheries managers include:
- Streamline Internet data access by user group categorization.
- Utilize GPS technology to deliver data to angler on the water since their boats are frequently out of cell phone and weather radio range.
- Increase the flexibility of delivery systems to allow for both real-time and historical data within the same framework.

5) Gaps and in current data products, tools, and producers.

- Absence of a continental shelf current model.
- More observation station reporting real time wind and wave data are required.
- Near shore/estuarine water quality data (i.e. coastal river discharge (including information on how river flow impacts coastal water salinity, temperature and suspended sediments), dissolved oxygen level, harmful algal bloom incidence).
- Water column observations, specifically water temperature and current speed and direction.

6) Cultural, educational, and institutional obstacles.

- The scarcity of long term funding that guarantees continued improvement and sustainability of a coastal climatology product.
- The absence of ‘180-degree’ feedback mechanisms that allow end-users to provide suggestions of the improvement of coastal climatology products.
- Absence of technology transfer from product developer to end-user.
- Limited awareness of opportunities to access and use coastal climatology products.

7) Training for coastal climatology end-users.

- Broader education efforts that include legislators as well as product developers, researchers, and managers.
- Integrate coastal climatology product training into current National Marine Educators Association, Coast Guard Marine Safety Officer, aquarium outreach, and Seas Grant Extension Program activities.
- Better advertising of training activities.
- Develop and post on the web along with coastal climatology products case study or event studies that describe the previous use of specific products for fisheries management decisions.

Core Area: Coastal Natural Hazard Mitigation

Background

Numerous natural hazards including coastal storms, hurricanes, tropical cyclones, northeasters, and winter storms regularly threaten the southeastern United States. Severe meteorological and marine events often produce damages to property and loss of life from high winds, storm surge, flooding, and shoreline erosion. While the impact of hazardous events can be devastating to any physical environment, coastal ecosystems are particularly vulnerable to extreme changes or permanent alteration. Beyond concerns of ecosystem health and public safety, there are compelling economic reasons to develop a better understanding of hazard impacts on coastal communities. The coastline supports an estimated one out of every six jobs in the United States and one-third of the gross domestic product (NOAA 1998, NRC 1997). To mitigate or protect these assets from hazardous events coastal managers need improved access to scientific information as it pertains to coastal vulnerability. Developing a better understanding of information on severe meteorological and marine events and documenting their impacts will provide a rational and objective basis for making substantial coastal resource management and planning decisions. This informational foundation is essential to help federal, state, and local programs identify and prioritize the most appropriate and cost-effective coastal hazard mitigation strategies.

Problem statement: hazard mitigation through beach renourishment

Weather, climate, and marine information are essential for natural hazard mitigation, preparedness, forecasting, and real-time response. Workshop participants described the integration of this information within decision-making frameworks for several natural hazard scenarios. Coastal decision makers are faced with digesting atmospheric and marine information regarding a potential hazardous storm, and interfacing that with infrastructure vulnerabilities to determine a course of action regarding population evacuation and securing and closing of industrial operations such as harbor facilities, non-personal automobile transportation, power stations, and manufacturing facilities. The question of hazard mitigation is less time critical, but equally complex in reducing uncertainty for planning strategies. In this report, we will illustrate the use of weather, climate, and marine information in hazard mitigation through beach renourishment. Beach renourishment or the replacement of sand on eroding beaches is a means of hazard mitigation as well as improving the beach quality and value of property near the beach.

Natural shorelines in the southeastern United States often exhibit some form of beach structure, with shallow near shore bathymetry, a foreshore or beach face, and a backshore (Davis and Fitzgerald 2003). Some beach environments are composed of dunes or built structures on the landward edge. Beaches can be categorized as either dissipative or reflective. Dissipative beaches have a gently slope between the near shore and the backshore. This gently slope allows for the gradual absorption of wave energy. Reflective beaches have steep faces that absorb much of the wave energy. Dissipative beaches typically accrete or gain sand while reflective beaches typically loose sand or erode. There are many ways to rebuild a beach and many reasons for doing so. Renourishment may provide mitigation from coastal storms but may provide only limited protection from strong hurricanes (Category 3 or greater). Hard shoreline stabilization structures, such as groins, jetties, seawalls, and bulkheads provide limited protection of coastal properties from strong hurricanes. These structures either directly absorb or divert wave energy to nearby locations along the coastline. They typically interrupt the natural flow of sand along coastlines by reducing or increasing the amount of suspended sand particle or by altering the current's direction and speed that in turn alters the locations of scouring and deposition. Hard stabilizers rarely provide long-term solutions to hazard mitigation and coastal erosion (Howard *et al.* 1985).

To stabilize or rebuild a beach, compatible sand is dredged and pumped from offshore sand bars or hauled overland by trucks and spread along the shore to create a dissipative surface. Beach renourishment is an anthropogenic component to beach dynamics. As nourished beaches erode under natural wave action, offshore sand bars may grow. This offshore bar may in turn cause waves to break further off shore and consequently slow the natural process of beach erosion. The replenishment material needs to have a texture similar to the existing material but not too fine as to be rapidly eroded or too course with shell fragments as to limit the use of the beach for recreation. The coarseness of nourishment material will partly contribute to the longevity of a renourishment project as well as the cost. Coastal storms, however, may destroy a renourishment project well before it expected lifetime.

After identification of locations in need of beach nourishment, planning activities include assessments of environmental and biological impacts as well as economic feasibility (NRC 1995). Economic assessments should consider the periodic maintenance from normal wave action and coarseness of fill material as well as maintenance from severe storms that may cause catastrophic scouring (Howard *et al*. 1985). A well designed environmental monitoring program that includes weather marine observations or modeling is an important part of planning for beach renourishment and essential to determining the success of the renourishment. Physical monitoring should continue beyond a construction phase and into performance evaluation and operational phases. Continuous monitoring would allow for the definition of baseline or expected conditions as well as annual or seasonal departures.

While considering the economic feasibilities and structural aspects of a project, marine and atmospheric climatology – historical information – may provide an approximation of beach renourishment performance (NRC 1995). Historical information may include sea level trends, astronomical tides, wave and current climatology, and severe storm climatology. This information would describe the expected and trends in physical processes that control the creation or destruction of beaches. Near-real time physical monitoring should include waves, currents, water levels, and weather conditions near the renourishment site. The processes of beach erosion or accretion are primarily controlled by waves and water level. Wind is a dominant physical process on the back beach or dune area where it has a role in beach erosion. As waves break against the beach or underlying surface sediment is disturbed and suspended in the water column. Currents may then transport suspended sediment.

Table 6 Summary descriptions of data needs, access information, relative costs and quality for hazard mitigation through beach renourishment.

DATA OR PRODUCT	SOURCES	ACCESS	COST	QUALITY/WEAKNESS
Sea level trends	NOAA NOS CO-OPS	Internet	Free	Limited locations for which data is available.
Wave climatology	Ocean Weather Inc.	Internet	Free, $$	Limited locations for which data is available, assumptions of gridding interpolation algorithms.
Real-time waves, currents, water levels, weather conditions from buoy or pier site	NOAA NDBC, Ocean Weather Inc., Buoyweather.com, Weather Underground, NCEP, FNMOC	Internet	Free, $$	Location of buoys away from study area and poor spatial resolution of buoy network.
Tropical storm forecasts	NOAA NHC	Internet, satellite	Free, third-party subscription	Short lead-time of forecasts and user's low confidence in accuracy.
Tides	NOAA NOS CO-OPS	Internet	Free	Limited locations for which data is available

Enumeration of resources and logistics for integration of weather, climate, and marine information in hazard mitigation

1) Data and analytical tools needed to produce the product.
   - Weather:
     ? Wind direction and speed to assess hazardous material release and exposure.
     ? Tropical storm and hurricane wind speed forecasts and other text products (e.g., warnings, watches, strike probabilities, etc.). Present conditions of a tropical storm and forecast changes in location, size, and intensity of the storm.
     ? Tornado and severe thunderstorm warnings.
     ? ALOHA, HUREVAC, and HURTRAC software.
   - Climate:
     ? Frequency of natural hazard events, such as climatology of hurricanes.
     ? Hindcast wind and wave data: numerical simulation of past wind and wave conditions. Multi-year time series of wind speed and direction and wave parameters at 1-hour intervals wave height, period, and direction. Time series are available for a

densely spaced series of nearshore points along the U.S. coastline (in water depths of 15-20 m) and a less-dense series of points in deep water (water depths of 100 m or more).

- Impacts:
  - ? Flood inundation models.
  - ? Storm surge model (e.g., NWS model called SLOSH that maps the local storm surge flooding for various levels of tropical storm intensity and storm track to the coastline).

2) Sources for the data and analytical tools and cost and suitability to core area.

- NOAA:
  - ? National Data Buoy Center **http://seaboard.ndbc.noaa.gov/index.shtml**
  - ? National Hurricane Center: "Special priority is placed on identifying the sections of coastline expected to be influenced by landfall of the hurricane, the wind and tide to be experienced during passage of the hurricane, and the timing of such conditions" (NRC 1989). **http://www.nhc.noaa.gov/**
  - ? National Weather Service Local Forecast Office **http://www.nhc.noaa.gov/**
  - ? National Climate Data Center **http://www.ncdc.noaa.gov/oa/ncdc.html**
  - ? Regional Climate Centers **http://www.nrcc.cornell.edu/other_rcc.html**
  - ? National Ocean Service, Center for Operational Oceanographic Products and Services **http://www.co-ops.nos.noaa.gov/**
  - ? NWS, NCEP Marine Modeling and Analysis Branch **http://polar.wwb.noaa.gov/**
- U.S. Army Corps of Engineers **http://www.usace.army.mil/**
- United States Navy Fleet Numerical Meteorological and Oceanographic Center **https://www.fnmoc.navy.mil/**
- National Lightning Data Network **http://www.crh.noaa.gov/pub/ltg.shtml**
- State Climatology Offices **http://www.ncdc.noaa.gov/oa/climate/stateclimatologists.html**
- Ocean Weather Incorporated **http://www.oceanweather.com/data/index.html**
- Buoyweather.com **http://www.buoyweather.com/**
- Weather Underground Marine Weather **http://www.wunderground.com/MAR/AM/**
- Participants indicated that access to free data and analytical tools is one of, if not the most important motivating feature in product selection. Therefore, the majority of data and analytical tools that they utilize are an amalgamation of low cost/free offerings.

3) Present format of the data and analytical tools and any changes needed.

- Almost all of the data currently available for mitigation of natural hazards are available through the Internet or FTP in digital format. This format is useful in that data can be quickly integrated into available software for analysis. It was noted by end-users that a wide array of data types and formats are used and that readily available Metadata is imperative to integrate the different databases. In addition, the natural hazard managers identified the following data format issues.
  - ? Digital weather and climate data downloaded over the web needs geo-spatial reference for the creation of maps.
  - ? Summary sheets for wave data provided by the National Data Buoy Center so that end-users can determine if breaks in data collection have occurred.

4) Accessibility of the data.
   - Climate, weather, and marine data are easily accessed by natural hazard managers. Data provided over the Internet is preferred over other formats. However, the accessibility of the weather and climate data can be improved through the following means:
     - ? Scientific websites are often not in the format of or easily understood by end-users.
     - ? A recent NESDIS users conference improvement of web access through format, design and content was discussed and end-users suggest the recommendations at this conference should be reviewed by NOAA, especially improvements to parts of USGS and Bureau of Transportation web sites.
     - ? The ideal format for access to coastal climatology products is "through a dynamic, web-based system accessed by a variety of users to build and manage their customized products and solutions."

5) Gaps or weaknesses in current data, products, tools, or providers.
   - Observations:
     - ? Expand and enhance C-MAN buoy system with archived information for use by structural engineers.
     - ? More inshore observations of waves, wind, and sea breeze with investment in directional wave gauges.
     - ? Wind data at 10 meters above the ground during storm events for use in building design and engineering.
   - Forecasts:
     - ? Forecast of ocean conditions during storms for shipping concerns.
     - ? An El Niño/La Niña or seasonal forecast product combined with near shore beach erosion models to predict erosion by event and by area on a sub-county basis.
   - Models / Climatology:
     - ? Observational data on severs storm climatology may be inadequate at capturing variability and extremes for newly developed areas. Modeling severe storm potential may help approximate expected ranges of storm impacts, including erosion, in under sampled areas.
     - ? Event-based data and tornado information with spatial path and impact data mapping.

6) Cultural, educational, and institutional obstacles.
   - Lack of consensus among scientific community in interpretation of results and utility of a product. Especially for costly beach renourishment products. Ultimate use of products may be overshadowed by return on investment for high-value coastal properties.
   - Potential computer and technology skills limitations of end-users.
   - Development of effective partnerships between organizations to manage and monitor resources, organizations that regulate, and the end users. Potential confusion about inherently government services versus private sector services. Questions on competing or redundant agency missions, policies, and institutions.

7) Training for coastal climatology end-users.
   - Provide training modules for specific user groups (e.g., for most local areas, storm tide simulations should be performed to support planning studies for decision making NRC [1989]). Training for NPS pollution, for example, might include the use of irrigation

schedules for water consumption and optimal conditions for pesticide applications. Training levels should be geared to a user group's level of knowledge and complexity of integration.
- Provide funding for K-12 education component for students and teachers and collaborate outreach with existing agencies to provide training (i.e. Sea Grant, Cooperative Extension, FEMA).
- Ensure media involvement to provide advertising and publicity for coastal climatology product.

Core Area: Recreation and Tourism

Background

Climate, weather, and outdoor recreation are connected in many diverse ways. Though the existing landscape determines which outdoor activities take place (e.g., boating needs water and rock climbing requires cliffs), weather and climate determines when outdoor activities take place and affect vacationers decisions about holiday destinations. Unexpected weather – heavy rain – can ruin a holiday, while unexpected climate – rainy summers –can have significant impacts on holiday-season economies. In addition, weather and climate are an important factor in both financial terms for tourism operators and the personal experiences of tourists (Table 7). Use of climate information in recreation and tourism ranges from locating recreational facilities, or determining the length of the recreation season during which a facility will operate, to planning future activities involving personal decisions of when and where to go for a holiday (de Freitas 2001). Depending on the weather sensitivity of the recreational activity, climatic information can aid the planning, scheduling, and promoting alternative indoor entertainment (Perry 1997, de Freitas 2001). Climate information can also be used in publicity campaigns to label expectations of climate at certain locations (Perry 1997).

Table 7 Weather and climate parameters, their significance, and their impact on recreation and tourism (adapted from de Freitas 1990 and de Freitas 2001).

Weather or climate parameter	*SIGNIFICANCE*	*IMPACT*
Aesthetic: [1]Sunshine/cloudiness/visibility [2]Day length	[1]Overall quality of experience. [2]Convenience.	[1]Satisfaction and enjoyment and attractiveness of destination. [2]Hours of daylight available for chosen activity.
Physical: [1]Wind [2]Rain [3]Snow [4]Ice	[1]Annoyance. [2]Annoyance, charm [3]Possibility of winter sports [4]Danger	[1]Blown belongings, sand, and dust. [2]Wetting, reduced visibility, enjoyment. [3]Participation in winter sports. [4]Tumbles, personal injury,

[5]Severe weather [6]Air quality [7]Ultraviolet radiation	[5]Annoyance, danger [6]Annoyance, danger [7]Danger, attraction	damage to property. [5]All of above [6]Health, physical wellbeing, allergies [7]Health, suntan, sunburn
Thermal: [1]Integrated effects of air temperature, wind, solar radiation, humidity, longwave radiation, and metabolic rate.	[1]Thermal comfort, therapeutic, restorative	[1]Environmental stress, physiological strain, hypo- and hyperthermia, and potential for recuperation

Problem statement: coastal water sports

One sector of tourism in the coastal southeastern United States that is particularly sensitive to climate and weather conditions is coastal water sports and recreation. Such tourism services include charter boat fishing, sailboat and sea kayak rental, and parasailing. For example, a sea kayaker must assess air and water temperature, wind speed and direction, and ebb and f1low tide in order to plan a successful and enjoyable trip (Bannon and Giffen 1997). Surfing is coastal water sport that has become increasingly popular, particularly on the Eastern coast of the United States. From New York to Florida, beach rental shops provide a wide variety of wake boards, boogie boards, and surfboards to customers in addition to surf lessons. Recently, this increased enthusiasm for surfing has manifested itself in the form of surf camps (Civelli 2003, personal communication). Surf camps provide residents and vacationers surfing lessons for a series of days and are model after recreational summer day camps. Such camps are particularly popular with families since children are provided with structured daily activities for an entire vacation. In order for such surf related commerce to be successful, the managers of the camps must be able to understand the link between weather, climate and wave conditions in order to manage seasonal budgets, hire staff, and plan and supervise daily surfing activities.

The climate, weather, and oceanographic features that are required to properly assess seasonal and daily surf conditions include ground swell, wind direction, tide schedule, local bathymetry and location of man-made structures such as jetties (Unger 2003). For example, a surfer at Wrightsville Beach in North Carolina will use moored C-MAN buoy observations along the southeastern United States coast (Canaveral north to Frying Pan Shoals) and available wave forecast models to predict, through there own experience, wave and swell conditions in Onslow Bay and Wrightsville Beach. Simply put, such a person is tracking the propagation of waves along the east coast and attempting to interpolate data form buoys to their specific location. This reliance upon personal experience to forecast wave conditions causes people vacationing in the area, new to the water sport, or with little training in climatology and oceanography to be unable to accurately predict surf conditions. A coastal climatology that would be useful for costal water sport enthusiasts must be able to perform the tasks the experienced surfer or participant does on their own, predict waves as they propagate along the southeastern coast and predict the conditions for specific open bay shorelines.

Table 8 Summary descriptions of data needs, access information, relative costs and quality for coastal water sports.

DATA OR PRODUCT	SOURCES	ACCESS	COST	QUALITY/WEAKNESS
Sea level trends	NOAA NOS CO-OPS	Internet	Free	Limited locations for which data is available.
Wave climatology	Ocean Weather Inc.	Internet	Free, $$	Limited locations for which data is available, assumptions of gridding interpolation algorithms.
Real-time waves, currents, water levels, weather conditions from buoy or pier site	NOAA NDBC, Ocean Weather Inc., Buoyweather.com, Weather Underground, Surfline, NCEP, FNMOC	Internet	Free, $$	Location of buoys away from study area and poor spatial resolution of buoy network.
Seasonal and monthly climate forecasts	NOAA CPC	Internet	Free	Generalized spatial patterns. Lower skill during some phases.
Tropical storm forecasts	NOAA NHC	Internet, satellite	Free, third-party subscription	Short lead-time of forecasts and user's low confidence in accuracy.
Tides	NOAA NOS CO-OPS	Internet	Free	Limited locations for which data is available

Enumeration of resources and logistics for integration of weather, climate, and marine information in coastal water sports

1) Data and analytical tools needed to produce the product.
   - Local historical and real time tide conditions.
   - Local historical and real time wind speed and direction observations at 5-15 minute intervals.
   - Swell conditions 100 miles out from shore, either satellite or buoy observations.
   - Current wave conditions and forecasts at 15 minute intervals (height, speed, where, and when).
   - Local historical and real time water temperature.
   - Local rip tide observations and predictions.

2) Sources for the data and analytical tools and cost and suitability to core area.
   - NOAA:
     ? National Data Buoy Center **http://seaboard.ndbc.noaa.gov/index.shtml**
     ? C-MAN Buoy Data Archive **http://seaboard.ndbc.noaa.gov/Maps/southeast_hist.shtml**
     ? National Hurricane Center **http://www.nhc.noaa.gov/**
     ? National Weather Service Local Forecast Office **http://www.nhc.noaa.gov/**
     ? National Climate Data Center **http://www.ncdc.noaa.gov/oa/ncdc.html**
     ? National Ocean Service, Center for Operational Oceanographic Products and Services **http://www.co-ops.nos.noaa.gov/**

? NWS, NCEP Marine Modeling and Analysis Branch **http://polar.wwb.noaa.gov/**

- United States Navy Fleet Numerical Meteorological and Oceanographic Center **https://www.fnmoc.navy.mil/**
- Surfline **http://surfline.com/home/index.cfm**
- Ocean Weather Incorporated **http://www.oceanweather.com/data/index.html**
- Buoyweather.com **http://www.buoyweathe r.com/**
- Weather Underground Marine Weather **http://www.wunderground.com/MAR/AM/**
- Participants indicated that access to free data and analytical tools is one of, if not the most important motivating feature in product selection. Therefore, the majority of data and analytical tools that they utilize are an amalgamation of low cost/free offerings.

3) Present format of the data and analytical tool and changes needed.
   - The format of the data and analytical tools is digital format accessed through the Internet by FTP. It should be noted that the objective of recreation managers is less of a research analysis focus as assessment of conditions focus. Thus, web delivery systems should be designed to convey landscape conditions as opposed to data for analysis.

4) Accessibility of data.
   - Scientific websites are not easily understood by recreation managers.
   - All data and products should be personalized to the end-user. Web sites should have options for graphics, text, model analyses, etc.
   - Web pages should include more visualization tools.
   - Delivery systems should be expanded to include cell phone voice messaging, text messaging, or e-mail delivery systems.

5) Gaps or weaknesses in current data, products, tools, or providers.
   - More inshore data (waves, wind, sea breeze data) is required including accurate wave forecasts developed from directional wave gauges. The current scale of observation does correspond with the scale of decision making.
   - Current moored buoys, especially in the Carolinas, exist over shoals (i.e. Frying Pan Shoals and Diamond Shoals) and do no represent surf conditions in open bays, such as Onslow Bay. The result is that surfers and other water sport enthusiasts must interpret data provided by shallow water cites and hypothesize as to the wave conditions in an open bay environment.
   - Development of models to be used by end-users with limited knowledge of meteorology and oceanography including more visualization tools and Surf Cameras.

6) Cultural, educational, and institutional obstacles.
   - There is competition between private and public sectors for providing data and products. Specifically, such competition causes confusion in terms of the quality of a data set, i.e. can private data sets be trusted? In addition, the competition can cause a redundancy in data collection causing fewer funds to be available for monitoring different coastal climatology parameters observed.
   - Since the government has responsibility to such a large variety of end-users, there is an inherent inability to customize coastal climatology products to specific end-user groups.

- There is a lack of onshore observation locations along the southeastern United States coast.
- A need to merge data sets for complete list of coastal climatology observations. In particular, rarely are terrestrial and inshore marine observations available within the same data set.
- Different Quality Assurance/Quality Control standards between entities collecting data cause different levels of confidence in different types of data.

7) Training for coastal climatology end-users.
   - Conference participants recognized that effective coastal climatology products for recreation will require significant training of end-users in the fundamental oceanography and meteorology concepts, more so than any other core area, due to the absence of formal training of managers and end-users.

Core Area: Coastal Transportation

Background

Coastal transportation encompasses a large variety of activities including car and truck traffic on coastal roads, private and commercial air traffic from coastal airports, and pleasure and commercial boating on the Intracoastal Waterway and inshore waters. Climate influences long-range planning for coastal transportation while weather affects all of these transportation activities and decision-making, particularly those concerning safety. Fog, heavy rain events, flooding, small craft advisories, and gale warnings require accurate prediction in order to avoid accidents, injuries and deaths, and efficient travel times. Landreneau (2001) found that Florida, North Carolina, and South Carolina rank first through third over the past 100 years in Atlantic coast hurricane strikes. Over that time, 17%, of tropical cyclones passed within 300 miles of the Carolinas. Although damage associated with category 3 through 5 hurricanes is typically due to the winds, in the Carolinas categories 2 and 3 hurricanes have been the most damaging, because of flooding across the broad flat coastal plain (www.carocoops.org). This mock up will focus upon the impact of tropical systems (storms, depressions, and hurricanes) upon coastal transportation, particularly in the form of hurricane evacuations of coastal communities. Hurricane evacuations involve decisions regarding the time and route of the evacuation of coastal residences due to hurricane landfall in order to ensure safety from wind and flooding damage.

Problem statement: hurricane evacuation planning and implementation

The goal of hurricane evacuation planners is to reduce the economic and human life loss through the prevention of injurious effects as opposed to stopping the hazard itself (Burton *et al*. 1993). The key to successfully meeting this goal is the decision upon an appropriate evacuation time. Evacuation time is defined as the amount of time before the hurricane eye making landfall that allows threatened residents to move to safety (Godschalk *et al.* 1993). The evacuation time is composed of both clearance time and pre-landfall hazards time. The clearance time represents the time required by residents to mobilize and travel to safety, including queuing delay time (USACE 1993). The pre-landfall time represents the time before landfall in which evacuation routes become hazardous and unsafe due to gale force winds and flooding (Godschalk *et al*. 1993). In order to effectively plan for evacuation time, hazard managers must first possess knowledge of the position of hurricane landfall. Through the knowledge of hurricane landfall, planners are then able to estimate areas of high winds, heavy rain, and potential flooding or areas for evacuees to avoid. A coastal climatology can serve most importantly as preparatory tool for transportation planners and managers. Specifically, a detailed coastal climatology of hurricane landfall can allow transportation officials to target areas that have experienced evacuation difficulties in the past and how to avoid such difficulties in the future. Such assessment of difficulties can include areas that have experienced high wind damage in terms of downed trees and traffic signs, flooding of roadways, and hydroplaning due to heavy rainfall.

Coastal climatology workshop participants identified hurricane evacuation as an activity with significant economic impact. One program participant estimated that hurricane evacuation in the state of Georgia costs approximately $1million per mile. Therefore, even in a state with a short coastline, such as Georgia, a hurricane evacuation can cost approximately $90-100 million, under scoring the importance of planning for an efficient, timely evacuation.

In addition, accurate evacuation times are imperative for hazards managers because residents must perceive the evacuation orders as "trustworthy". If hazard managers create a series of inaccurate evacuation orders, coastal residents may develop a mistrust of the order and not evacuate at the appropriate time. Such a relationship between coastal community officials and residents has been labeled a "crying wolf syndrome" (Godschalk *et al*. 1993). For example, phone interviews of coastal North Carolina residents indicated that 30% of interviewees would not evacuate once given the order from local officials due to previous erroneous evacuation times.

Table 9 Summary descriptions of data needs, access information, relative costs and quality for evacuation planning and implementation.

DATA OR PRODUCT	SOURCES	ACCESS	COST	QUALITY/WEAKNESS
Precipitation and stream flow climatology	NOAA NCDC, USGS	Internet, CD-ROM	$	Limited spatial coverage of gauged watersheds and bias towards large watersheds.
Real-time stream flow	USGS, NOAA NWS	Internet	Free	Limited spatial coverage of gauged watersheds and bias towards large watersheds.
Weather forecasts to 10 days	NOAA NWS	Internet	Free, third-party subscription	End-user time intensive.
Seasonal and monthly climate forecasts	NOAA CPC	Internet	Free	Generalized spatial patterns. Lower skill during some phases.

Hourly precipitation radar	Real-time NOAA NWS	Internet, satellite	Free, third-party subscription	Data intensive and difficult to format for common software (GIS).
	Archive NOAA NCDC	Internet	$$	Data intensive and difficult to format for common software (GIS).

Enumeration of resources and logistics for integration of weather, climate, and marine information in hurricane evacuation

1) Data and analytical tools needed to produce the product.
   - Historic and current rainfall data along major coastal transportation/evacuation routes to predict flood areas.
   - Historic and current flood forecasts along major coastal transportation/evacuation routes (such models not only include hydroclimatic data but also integrate topography, soils, and land use in drainage basins).
   - Historic and current wind speed along major transportation/evacuation routes to assess areas prone to wind damage.
   - HUREVAC and HURTRAC software.
   - Hurricane track and intensity forecasts to predict location of hurricane landfall and high wind areas.
   - Storm surge models to assess coastal flooding, dune failure, and road failure.

2) Sources for the data and analytical tools and cost and suitability to core area.
   - NOAA
     ? National Climate Data Center **http://www.ncdc.noaa.gov/oa/ncdc.html**
     ? Regional Climate Centers **http://www.nrcc.cornell.edu/other_rcc.html**
     ? National Weather Service Local Forecast Offices **http://www.nws.noaa.gov/**
     ? National Hurricane Center **http://www.nhc.noaa.gov/**
     ? Climate Prediction Center **http://www.cpc.ncep.noaa.gov/**
   - United States Geologic Survey, Water Resources Division **http://water.usgs.gov/**
   - State Climatology Offices **http://www.ncdc.noaa.gov/oa/climate/stateclimatologists.html**
   - Participants indicated that access to free data and analytical tools is one of the most important motivating features in product selection. Therefore, the majority of data and analytical tools that they utilize are an amalgamation of low cost/free offerings.

3) Present format of the data and analytical tool and any change needed.
   - The dominant format of the data and analytical tools is digital format accessed through the Internet or FTP. This format is very useful for integrating data into available software for analysis. However, personalizing data to the end user will improve its accessibility. Such a personalization would include a wide array of graphic formats, text format, and model analyses from which the user can choose.

4) Accessibility of data.

- Although hurricane evacuation managers access data and analytical tools through the Internet, diminishing the scientific and technical jargon that causes barriers for end-users would improve the accessibility to the data. In addition, since NOAA transmits many of the severe weather warnings via weather radio, efforts should be directed to improving the efficacy of these announcements by educating the public how to access and understand evacuation orders.

5) Gaps or weaknesses in current data, products, tools or providers.
   - An absence of sub-county hurricane wind data.
   - Hurricane track forecasts need to a better explanation in regard to the levels of confidence in track probabilities. Specifically, how can a costal emergency manager integrate confidence in South Atlantic Basin scale track forecasts into county and sub-county emergency management decisions.
   - Not enough inshore data (waves, wind) is available at the scale at which emergency management decision are made, particularly directional wave gauges. A review of current NOAA supported moored buoys indicates that communities located between major metropolitan areas and associated mooted buoys in the Southeast (Virginia Beach VA, Cape Hatteras NC, Wilmington NC, Charleston SC, Savannah GA, Jacksonville FL, Cape Canaveral FL, and Tampa FL) are faced with the challenge of extrapolating buoy info to their own location. Such extrapolation of data may be beyond the technical resources of small coastal community resources.
   - A product that integrates historic and real–time by sub-basin to assist with river flow forecast.
   - Low spatial density of rain gauges along transportation routes.

6) Cultural, educational, and institutional obstacles.
   - Competition between private and public sector to provide data. Specifically, such competition causes confusion in terms of the quality of a data set, i.e. can private data sets be trusted? In addition, the competition can cause a redundancy in data collection causing fewer funds to be available for monitoring different coastal climatology parameters observed.
   - Since the government has responsibility to such a large variety of end-users, there is an inherent ability to customize coastal climatology products to specific end-user groups.
   - An overall lack of onshore observation locations along the southeastern United States coast.
   - A need to merge data sets for complete list of coastal climatology observations. In particular, rarely are terrestrial and inshore marine observations available within the same data set.
   - Different Quality Assurance/Quality Control standards between entities collecting data cause different levels of confidence in different types of data.
   - Insufficient governmental funding for the development of coastal climatology products.

7) Training for coastal climatology end users.
   - Technical training for decision makers in addition to technical/scientific support staff.
   - Communication training for planner and engineers regarding effective communication techniques with commissioners and managers.

- Training on how to integrate visualization tools with coastal climatology products.

Core Area: Coastal Water Quality and Consumption

Background

Precipitation patterns impact stream flow, reservoir storage, and groundwater levels that may result in the curtailment of water consumption. Increased temperature would increase evaporation losses, which results in increased customer demand such as landscape or agricultural irrigation. Reduced precipitation would compound water consumption stresses. We have found that a great deal of the information that water resource managers seek comes from the historical climate record and associated probabilities. For example, drought and extreme precipitation probabilities are composed of information from an historical instrumental record and seasonal forecasts. Understanding how ENSO events alter seasonal changes in precipitation and temperature is particularly important for water quality issues (Winstanley and Changnon 1999, Tufford *et a*l. 1998). In regions influenced by a strong ENSO signal, significant, and somewhat predictable seasonal variation in water quality can result. Such variation has been documented in coastal margins where changes in freshwater inputs affect estuarine salinity and biological communities (Lipp *et al*. 2001, Schmidt *et al*. 2002). Of particular importance to water quality in coastal environments is the existence of non-point source pollutants

Non-point source (NPS) pollution is a process of aggregating small quantities of natural and anthropogenic material from across large areas and depositing them in concentrated forms in other locations. In the southeastern United States, precipitation or irrigation runoff is the vehicle for aggregating NPS pollution and water resources such as rivers, lakes, and coastal areas are the deposition zones. The Environmental Protection Agency (1994) summarized NPS pollutants.

- Excess fertilizers, herbicides, and insecticides, fertilizers and manure including phosphorus, nitrogen, and potassium are applied to enhance production of agricultural crops. Pesticides, herbicides, and fungicides are used to kill pests and control the growth of weeds and fungus on agricultural lands and residential areas.
- Sediment from improperly managed construction sites, crop and forestlands, and eroding streambanks. Pollutants such as phosphorus, pathogens, and heavy metals may attach to soil particles and concentrate in the water bodies with the sediment.
- Salt can be deposited from poorly managed irrigation systems.
- Oil, grease, and toxic chemicals can be contained in commercial and residential runoff.
- Bacteria and nutrients can be leached or over-washed from livestock systems.

Problem statement: reducing non-point source pollution

Unnecessary or excessive application of fertilizers or pesticides can contaminate water through runoff, wind transport, and atmospheric deposition. Precipitation patterns affect agricultural runoff, which is often cited as one of the main contributors to NPS pollution in coastal waters, particularly coastal eutrophication (Nixon 1995). In aquatic ecosystems, these chemicals can cause excessive plant growth, can kill fish and wildlife, and can reduce the overall water quality for other purposes (e.g., recreation, drinking, industry, etc.). Appropriate application of fertilizers, including minimization of wind transport and implementation of integrated pest management techniques to make use of specific soil, climate, pest history, and crop information could reduce the source of NPS pollutants. Especially important is the collective knowledge of pollutant sources and the physical transport mechanisms.

Erosion and sedimentation can be reduced by applying management measures to control the volume and flow rate of runoff water, keep the soil in place, and reduce soil transport by wind. Seasonal and short-term weather forecasts can provide probabilities for increased precipitation and increased runoff. Minimizing construction during above average precipitation seasons may not be practical, but planning for above average precipitation by applying greater soil protection or scheduling less weather sensitive projects may help limit sedimentation and erosion.

Irrigation is applied in agricultural areas to replace insufficient precipitation during drought, to meet the moisture demands of crops with greater precipitation requirements, or to protect crops against freezing (Thompson 1999). Irrigation is often applied in residential areas to support turf grass or ornamental plants and shrubs. Excessive irrigation may enhance the runoff from agricultural or residential areas, thus contributing to NPS pollution in water bodies. Irrigation scheduling is relatively easy with knowledge of crop type, the soil's moisture holding capacity, the antecedent precipitation and temperature. Water budget or demand results (i.e., moisture surplus or deficit) may be calculated. Whether to apply irrigation or not would be determined by the demand (e.g., deficit), a probabilistic quantitative precipitation forecast, and the moisture sensitivity of the crop. Of course, the economic value of the decision (e.g., slight browning of turf grass or 50% reduction in yield of primary cash crop) would factor into irrigation decisions.

Because of their significant sources of animal waste, the explosion of industrial feedlot operations in the southeastern United States (especially swine) is a considerable water quality concern for coastal communities (Furuseth 1997). Precipitation and effluent runoff from poorly managed facilities can contain bacteria, nutrients, and oxygen-demanding substances that contaminate shellfishing areas and cause other major water quality problems (EPA 1994). These feedlots offer a unique management challenge in that animal waste is often applied to fields where evaporation helps diminish the negative impact of this waste. Such controversial spraying operations require significant knowledge of local weather conditions in order to be implemented successfully (Wax and Pote 1996). Figure 3 illustrates that drought conditions may not provide enough ambient moisture to dilute waste-lagoon effluent. In addition, heavy rains and floods can cause failure of waste holding lagoons, causing millions of gallons of waste to be released into local rivers and estuaries (Mallin 2000). Five to ten day precipitation forecasts would provide short-term management support of waste lagoons. Tropical storm forecasts would help lagoon managers avoid catastrophic failures. If lagoon managers could assign values to the simple relationship in Figure 3, antecedent moisture conditions and forecasts could be valuable tools for minimizing environmental impacts.

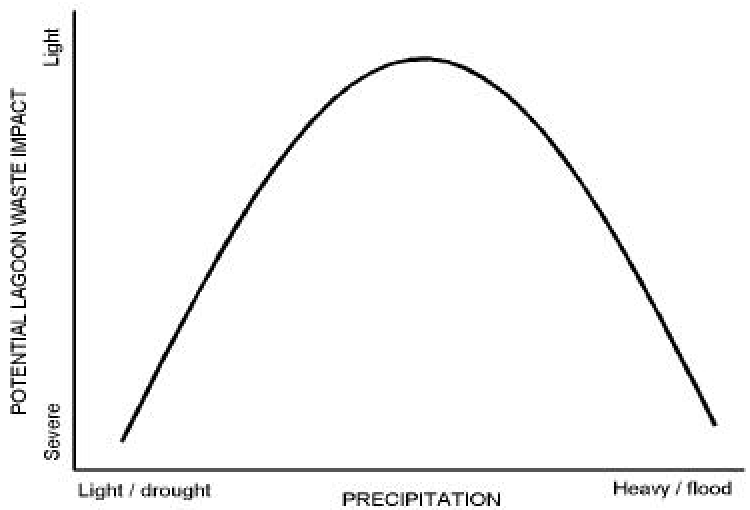

Figure 4 Generalized relationship between precipitation amount / intensity and negative environmental impacts of lagoon waste spraying or overflowing.

Table 10 Summary descriptions of data needs, access information, relative costs and quality for reducing non-point source pollution.

DATA OR PRODUCT	SOURCES	ACCESS	COST	QUALITY/WEAKNESS
Seasonal and monthly precipitation forecasts	NOAA CPC	Internet	Free	Generalized spatial patterns. Lower skill during some phases.
Weather forecasts to 10 days	NOAA NWS	Internet	Free, third-party subscription	End-user time intensive.
Tropical storm forecasts	NOAA NHC	Internet, satellite	Free, third-party subscription	Short lead time of forecasts and user's low confidence in accuracy.
Water-budget daily input: temperature, precipitation, soil moisture, solar radiation	NOAA NCDC, RCC, USDA, mesonetworks	Internet	$	Soil moisture and solar radiation measurements are not widely available
Radar precipitation	Real-time NOAA NWS	Internet, satellite	Free, third-party subscription	Data intensive and difficult to format for common software (GIS).
	Archive NOAA NCDC	Internet	$$	Data intensive and difficult to format for common software (GIS).

Enumeration of resources and logistics for integration of weather, climate, and marine information in reducing non-point source pollution

1) Data and analytical tools needed to produce the product.
   - Information for planning fertilizer or pesticide applications:
     - ? Daily and hourly wind direction and speed forecast to minimize dispersal of chemicals to non-target areas.
     - ? Daily and hourly precipitation forecast to minimize potential for chemical washout and runoff.
     - ? Antecedent moisture and temperature conditions to support chemical manufacturer's guidelines for application.
     - ? Weather information to support integrated pest management (i.e., do weather conditions support the existence of a pest in a particular location).
   - Information for reducing erosion and sedimentation:
     - ? Monthly or seasonal precipitation forecasts for planning large-scale construction projects.
     - ? Weekly precipitation forecast for short-term planning and abatement procedures.
   - Information for irrigation scheduling:
     - ? Antecedent precipitation and temperature (at least previous three months) to determine if water surplus or deficit exists.
     - ? Weekly precipitation and temperature forecast to project moisture conditions and the potential for overcoming or exceeding deficit.
   - Information for managing waste lagoons:
     - ? Frequency of natural hazard events, such as climatology of hurricanes.
     - ? Flood inundation and storm surge model (e.g., NWS model called SLOSH that maps the local storm surge flooding for various levels of tropical storm intensity and storm track to the coastline).
     - ? Tropical storm and hurricane wind speed forecasts and other text products (e.g., warnings, watches, strike probabilities, etc.).
     - ? Present conditions of a tropical storm and forecast changes in location, size, and intensity of the storm.

2) Source for the data and analytical tools and cost and suitability to core area.
   - NOAA:
     - ? National Weather Service Local Forecast Offices **http://www.nws.noaa.gov/organization.html**
     - ? National Hurricane Center **http://www.nhc.noaa.gov/**
     - ? National Climate Data Center **http://www.ncdc.noaa.gov/oa/ncdc.html**
     - ? Climate Prediction Center **http://www.cpc.ncep.noaa.gov/**
     - ? Regional Climate Centers **http://www.nrcc.cornell.edu/other_rcc.html**
   - United States Geologic Survey, Water Resources Division **http://water.usgs.gov/**
   - State Climatology Offices **http://www.ncdc.noaa.gov/oa/climate/stateclimatologists.html**
   - Participants indicated that access to free data and analytical tools is one of, if not the most important motivating feature in product selection. Therefore, the majority of data and analytical tools that they utilize are an amalgamation of low cost/free offerings.

3) Present format of data and analytical tools and any changes needed.
   - Hourly and daily near-real time weather observations are available through NOAA data providers in standard ASCII formats. Metadata such as geographical coordinates are readily available.
   - Short-term weather, seasonal climate, and tropical storm forecasts are available in text formats over the Internet or via satellite. Some of these products are in ASCII format while others are textual.
   - Radar products are available for many different time increments, such as 5-10 minute intervals, hourly precipitation totals, and storm total precipitation. Spatial resolution of these products may be as fine as 1.1 nautical mile grids.

4) Accessibility of the data.
   - Weather and climate data for reducing NPS pollution transport are easily accessed. Forecast, near-real time, and historical data are provided over the Internet. The accessibility of the weather and climate data can be improved through the following means:
     ? Revising websites for easy navigation and minimization of scientific and technical jargon.
     ? Personalizing web sites and tools for specific uses (e.g., irrigation scheduling).
     ? Providing multiple options for data and information output, such as tables, graphs, and maps.

5) Gaps or weaknesses in current data, products, tools, or providers
   - Recommended improvements in forecast products:
     ? Greater accuracy of weather and climate forecasting, including increased spatial and temporal resolution.
     ? Five to ten-day precipitation forecasts.
     ? Forecast hurricane tracks with increased confidence levels.
   - Recommended improvements for observational data:
     ? Improved standardization between geographic locations, including electronic reporting formats and near-real time reporting.
     ? Additional real time weather stations near sensitive NPS pollution sites.
     ? Sub-county wind direction and speed data for managing airborne pesticide / herbicide applications.
   - Recommended improvements in blended or derived products:
     ? Integrate real time and historical rainfall data by sub-basins to assist with river flow analysis and return periods for heavy precipitation events.

6) Cultural, educational, and institutional obstacles.
   - Controlling NPS pollution is a monitoring and regulatory function that has economic and lawful consequences. Use of weather and climate information may be attractive to regulators but not potential violators.
   - Dogmatic philosophy of applying pesticide, fertilizers, and irrigation under ill-informed management plans.
   - Untested perceptions that applying weather or climate-based management strategies is more costly than some other formulation of management decisions.

- Potential computer and technology skills limitations of end-users.
- Development of effective partnerships between organizations to manage and monitor resources, organizations that regulate, and the end users. Potential confusion about inherently government services versus private sector services. Questions on competing or redundant agency missions, policies, and institutions.

7) Training for coastal climatology end-users.
   - Provide training modules for specific user groups (e.g., agriculture, urban management, waste lagoon operators). Training for NPS pollution, for example, might include the use of irrigation schedules for water consumption and optimal conditions for pesticide applications. Training levels should be geared to a user group's level of knowledge and complexity of integration.
   - Provide funding for K-12 education component for students and teachers and collaborate outreach with existing agencies to provide training (i.e. Sea Grant, Cooperative Extension, Environmental Protection Agency).
   - Ensure media involvement to provide advertising and publicity for coastal climatology product.

SUMMARY RECOMMENDATIONS

Specific client problems involving decision making in coastal zones have been described. These client problems were derived from eight generalized user areas to illustrate the needs and processes that a coastal community decision maker may undertake. We did not set out to provide exhaustive sets of information within user areas nor do we expect to have exhausted all weather, climate, or marine related end-user areas. We have presented a cross section of the many uses for weather, climate, and marine information in the southeastern United States. This cross section represents a subset of similar problems across other coastal regions. Our findings provide valuable guidance for user expectations within specific applications as well as generalizations across core areas.

This section presents a coastal climatology research suggestion that would benefit multiple user areas in the southeastern United States. Coastal climatologies are unique because they would consist of a blending of marine and terrestrial-based atmospheric information and near-shore oceanographic parameters. Development of applications and databases would support coastal managers, specifically those faced with weather, climate, and marine-sensitive decisions. Coastal managers representing fisheries, recreation, transportation, and shoreline erosion concerns have expressed the need for "better" information about waves, currents, and winds within bays and near shore areas, roughly 5 kilometers from the shoreline. Exactly what is meant by "better" is unclear because the managers do not have sufficient background in the physical marine sciences, but the general feeling is that "better" means spatial resolution on the scale of counties or sub-counties, real-time reporting, and a means for placing real-time information into an historical perspective.

Perhaps one of the best efforts toward "better" coastal marine information in the southeastern United States comes from the NOAA-supported partnership among the University of South Carolina, North Carolina State University, and the University of North Carolina at Wilmington called Caro-COOPS or Carolinas Coastal Ocean Observing and Prediction System (www.carocoops.org). The initiative is based on instrumented arrays of coastal and offshore moorings that will be used to monitor and model estuarine and coastal ocean conditions, as well as develop predictive tools and ultimately forecasts. Although a central goal of Caro-COOPS is prediction of coastal ocean processes, such as storm surge modeling, it is based on real-time monitoring of oceanographic, hydrologic, and meteorological parameters. In 2003, Caro-COOPS began a deployment of nine moorings ranging from onshore to ~70 kilometers offshore (200 meters depth). The nine offshore moorings contain instrumentation for surface waves, current speed and direction at multiple levels, temperature, salinity, pressure, transmission, and fluorescence/chlorophyll. Five shore-based instrumentation towers record water level and four of these additionally record meteorological parameters.

A similar and collaborative Coastal Ocean Research and Monitoring Program (CORMP) at the University of North Carolina at Wilmington, maintains six instrumented moorings and one meteorological buoy in the Frying Pan Shoals region of the South Atlantic Bight. CORMP moorings were designed for research, but through collaboration with Caro-COOPS would be upgraded to operational monitoring through real-time communications. Although focused on improving predictive systems, Caro-COOPS provides valuable lessons for integrating coastal observations. Specifically three major advances in observing system are anticipated:

- *It establishes an extensive array of instrumented moorings in the South Atlantic Bight;*
- *It includes the development of a comprehensive data management system, essential for access to, and integration of, high quality, real-time data; the system will be designed to maximize flexibility and utility, with a view towards serving as a model or support for other coastal ocean observing systems;*
- *It incorporates an advanced suite of integrated models that will improve the predictive capacities of real-time physical data from coastal ocean instrumentation.*

The National Data Buoy Center maintains approximately 12 moored buoys or C-MAN stations off the coast of the Carolinas. The Skidaway Oceanographic Institute maintains two additional marine-based meteorological towers for the U.S. Navy. Collectively, these observation networks comprise at least 33 oceanic and atmospheric monitoring locations along the Carolina coast (Figure 5). As many as 12 additional locations have been instrumented but are undergoing testing or are waiting commissioning.

Additionally, there are as many as 20 hourly-reporting and 30 daily-reporting meteorological towers located in coastal counties of North and South Carolina. A majority of stations are owned and operated by the National Weather Service, but other institutions and Federal agencies also maintain towers. Moreover, plans to modernize the NWS Cooperative Observer program would transition many daily-reporting stations into hourly reporting stations.

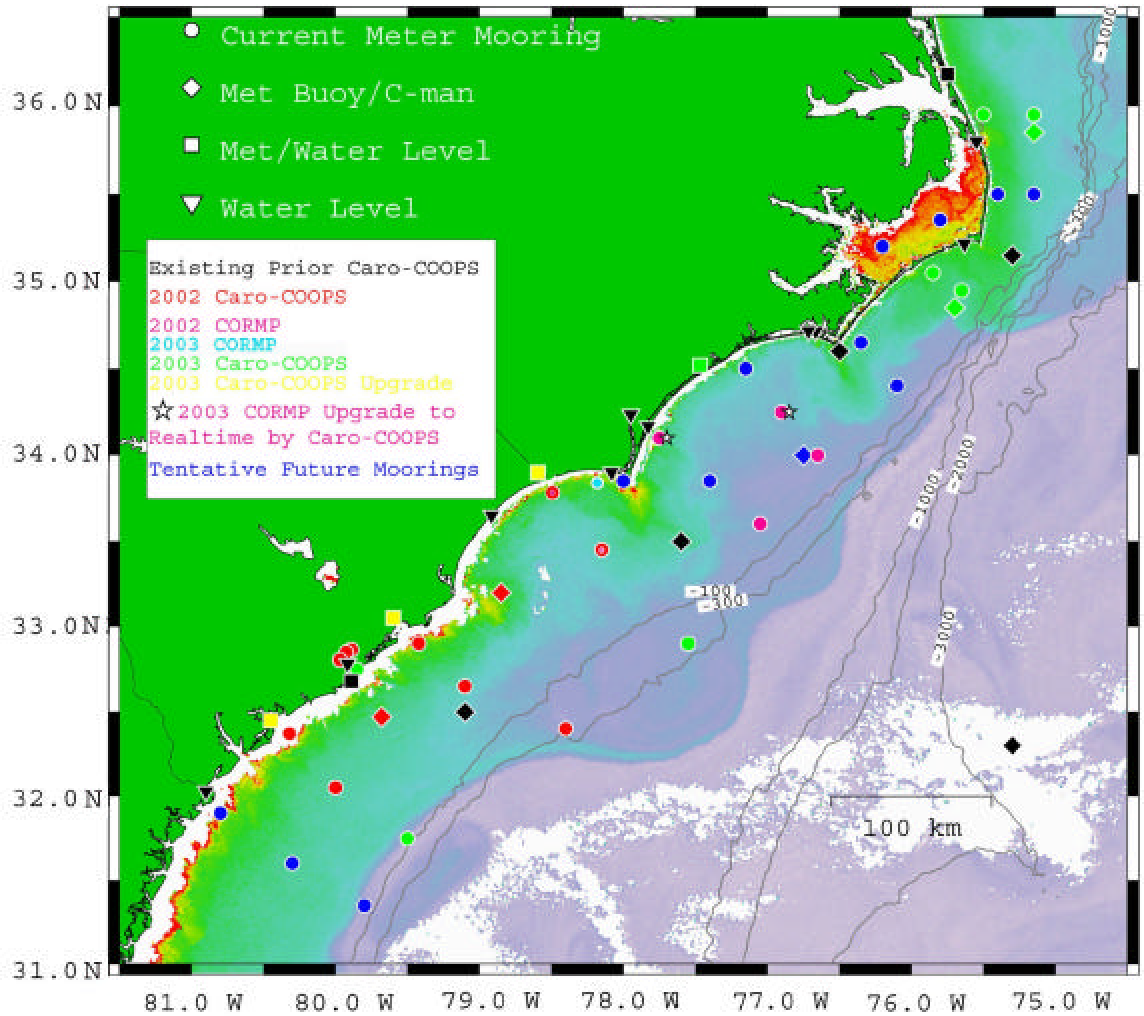

Figure 5 Spatial distribution along the Carolina coast of moorings, buoys, and on-shore instrumentation platforms from Caro-COOPS, CORMP, and C-MAN observing systems (source Len Pietrafesa).

Coastal climatology products should address the multitude of, differences between, and deficiencies throughout coastal-ocean observing systems. It is tempting to conclude that an inshore network of buoys is necessary to provide this information, but we are avoiding coming to this conclusion until we feel the alternatives, such as better models that use the existing monitoring network, have been adequately scoped. Through either the addition of more data collecting buoys, the integration of non-Federal observing system similar to Caro-COOPS or SEA-COOS objectives (www.seacoos.org), creation of accurate spatial interpolation, or modeling from the existing observation network, stakeholder needs may be met. A plan for producing this information, including assessments of the relative economic and societal benefits, is needed. The plan would cover everything from physical and social science research to training and delivery of the products. The geographic bounds of the initial plan would be North and South Carolina, but a broader coverage within the southeast may be pursued if the right opportunities present themselves.

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APPENDIX A

Agenda: Coastal Climatology Workshop Coastal Services Center, Charleston, SC

Tuesday October 21, 2003

Registration	8:00-9:00AM
Welcome, Opening Remarks, and Introductions -- Mike Janis, Southeast Regional Climate Center	9:00-9:10AM
Purpose & vision statements for Coastal Climatologies -- Jeff Payne, Deputy Director, NOAA, Coastal Services Center -- Thomas Karl, Director, NOAA, National Climate Data Center	9:10-9:40AM
Climate and Weather Impacts on Society & the Environment -- Len Pietrafesa, Professor of Marine, Earth & Atmospheric Sciences North Carolina State University	9:40-10:00AM
Morning Break	10:00-10:30AM
Review of terrestrial-based or climate observing systems -- Dan St. Jean, Science and Operations Officer Charleston, SC National Weather Service Forecast Office	10:30-11:00AM
Review of marine-based observing systems -- Suzanne Van Cooten, Chief Scientist Observing Systems Branch, National Data Buoy Center	11:00-11:30AM
Discussion of core areas and assignment of breakout sessions -- Doug Gamble, University of North Carolina at Wilmington	11:30AM-12:00PM
Catered Lunch	12:00-1:00PM
Working Group Session 1: Stakeholder decisions and needs	1:00-2:30PM
Afternoon Break	2:30-3:00PM
Working Group Session 1 continued	3:00-4:30PM
Evening Banquet	6:15PM

Wednesday October 22, 2003

Working Group Session 2: Stakeholder recommendations	8:30-10:00AM
Morning Break	10:00-10:30AM
Working Group Session 2 continued	10:30-12:00AM
Catered Lunch	12:00AM-1:00PM
Group Reports	1:00-2:00PM
Closing Comments	2:00PM
Adjourn	2:30PM

APPENDIX B

PARTICIPANT LIST: Coastal Climatology Workshop, Oct 21-22, 2003, Charleston, SC

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APPENDIX C

Specific areas of participant interest, expertise and concern not included in core area discussions:

- Monitoring and prediction of harmful algal blooms along the southeastern United States coast;
- Monitoring and prediction of storm water runoff into southeastern United States coastal waters;
- Integration of coastal climatology products into coastal intra-modal marine transportation;
- Integration of coastal climatology products into management (open and closing) of coastal shellfish grounds;
- Integration of coastal climatology products into coastal air quality management;
- Integration of coastal climatology products into recreation and tourism management (monitoring of carriage horse heat stress, changing of bus schedules, beach closures);
- Integration of coastal climatology products into management of rail transportation (track buckeling and wind hazards);
- Integration of coastal climatology products into forest fire prediction;
- Integration of coastal climatology products into management architectural designs and construction schedules;
- Integration of coastal climatology products into emergency management and mitigation (handling of hazardous materials, tornado evacuations, design of homes for high wind stress).

APPENDIX D

Questions for Working Groups

Session 1: 1-4:30PM, Tuesday October 21

1. Identify core-use areas within working group.
2. What weather or marine sensitive decisions, plans, or assessments does your agency make?
   a. Describe the time frames (i.e., decisions made daily or one year in advance).
   b. Describe motivations or value of decisions (i.e., money, safety).
3. To what extent is weather or marine information integrated into decisions, plans, or assessments?
   a. Describe the accessibility of the information and related analytical tools.
4. What type of weather or marine information is currently used in decisions, plans, or assessments?
   a. Describe how information is accessed (i.e., dynamic web, static CD)?
   b. Describe how information is integrated (i.e., through models or subjectively)?
   c. Describe the present format of the data and analytical tools.
5. How could decisions, plans, or assessments be improved with additional weather or marine information?
   a. Could additional decisions be made?
   b. Could uncertainty be reduced?

Expected summary: 1) key decisions or operations, 2) important data, and 3) common avenues for improvement.

Session 2: 8:30-12:00PM, Wednesday October 22

1. Itemize weather or marine information that would assist operations, including currently used and proposed information.
   a. Identify information gaps and assess the likelihood that current technology could fill those gaps.
   b. Can different weather and marine data be grouped together based upon type, format, delivery system, and period?
2. How should the information be provided?
   a. What formats should information be delivered (i.e., web, email)?
   b. What time frames?
   c. What spatial scales?
3. How would users like to manage information, synthesize information, and adapt to new technologies and new products?
   a. Identify analytical tools needed to produce a product.
   b. What are acceptable costs for information and analytical tools?
4. Provide recommendations for product support.
   a. Should NOAA provide focal points for specific information or products?

   b. Should NOAA provide web-based clearinghouses for product support?

5. Identify obstacles within the coastal management community that would impede the adoption coastal climatology products.

6. Describe the training that would be needed within the coastal management community to make use coastal climatology products.
   a. Identify and assess key training providers within the private sector and government capable of providing the training.

Expected summary: 1) most commonly required data, 2) ideal delivery system and management tools, 3) biggest obstacle to coastal climatologies, and 4) greatest training needs.